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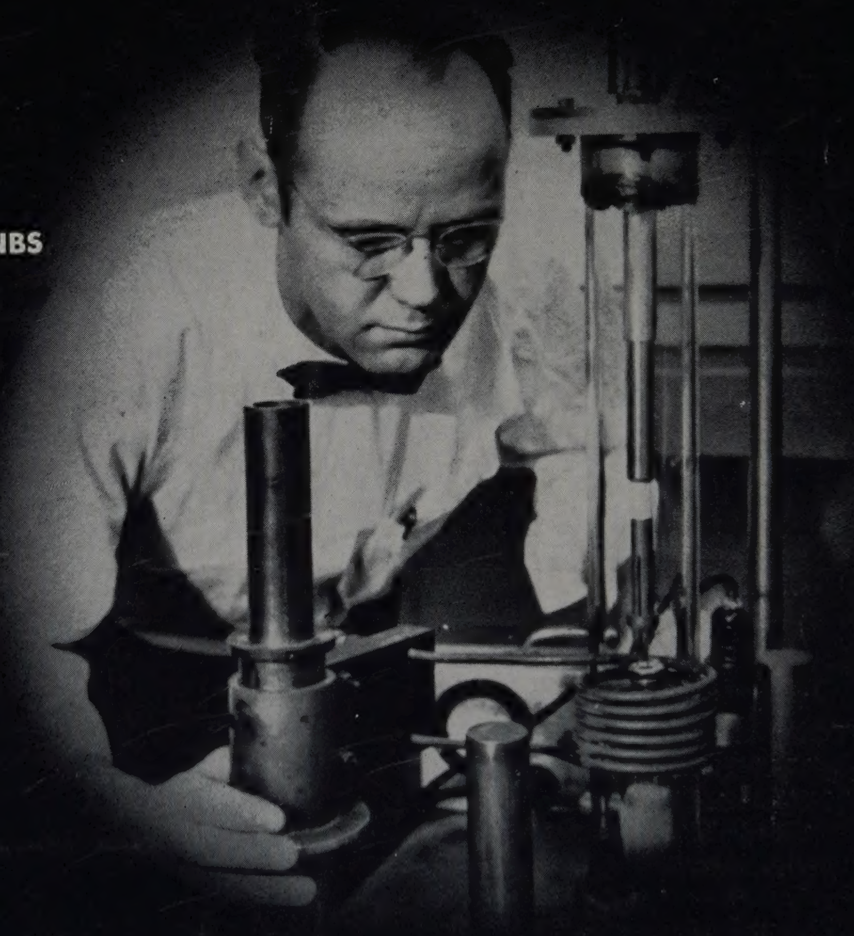

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A Practical Approach To Transistor Circuit Design

Counters Using Single Crystal Barium Titanate Capacitors

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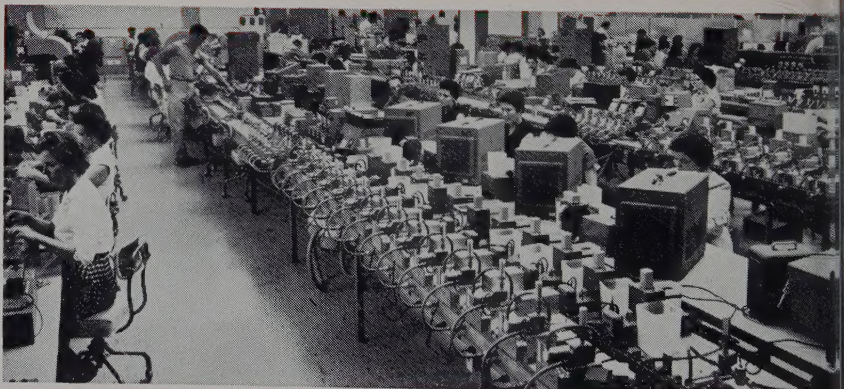

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(unless otherwise noted)

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I_{CBO}	Collector Reverse Current	V_{CB} = 30v	I_E = 0	—	1.0	μa
	at 150°C	V_{CB} = 30v	I_E = 0	—	100	μa
BV_{CBO}	Collector-Base Breakdown Voltage	I_{CBO} = 100μa	I_E = 0	60	—	v
BV_{CER}	Collector-Emitter Breakdown Voltage	I_{CER} = 100ma	R_{BE} = 10 ohms	40	—	v
BV_{EBO}	Emitter-Base Breakdown Voltage	I_{EBO} = 100μa	I_C = 0	5	—	v
h_{FE}*	D-C Forward Current Transfer Ratio	I_C = 150ma	V_{CE} = 10 v (2N696)	20	60	—
			(2N697)	40	120	—
V_{BE} (sat)*	Base-Emitter Saturation Voltage	I_C = 150ma	I_B = 15ma	—	1.3	v
V_{CE} (sat)*	Collector-Emitter Saturation Voltage	I_C = 150ma	I_B = 15ma	—	1.5	v
h_{fe}	A-C Common Emitter Forward Current Transfer Ratio	I_C = 50ma	V_C = 10v f = 20mc	2.5	—	—
C_{ob}	Collector Capacitance	I_E — 0ma	V_C = 10v	—	35	μμf

*Pulse conditions: length = 300μs ; duty cycle < 2%.

maximum ratings at 25°C ambient

Collector-Base Voltage	60v
Collector-Emitter Voltage (R_{BE} = 10 Ω)	40v
Emitter-Base Voltage	5v
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Total Device Dissipation at case temperature 25°C	2w
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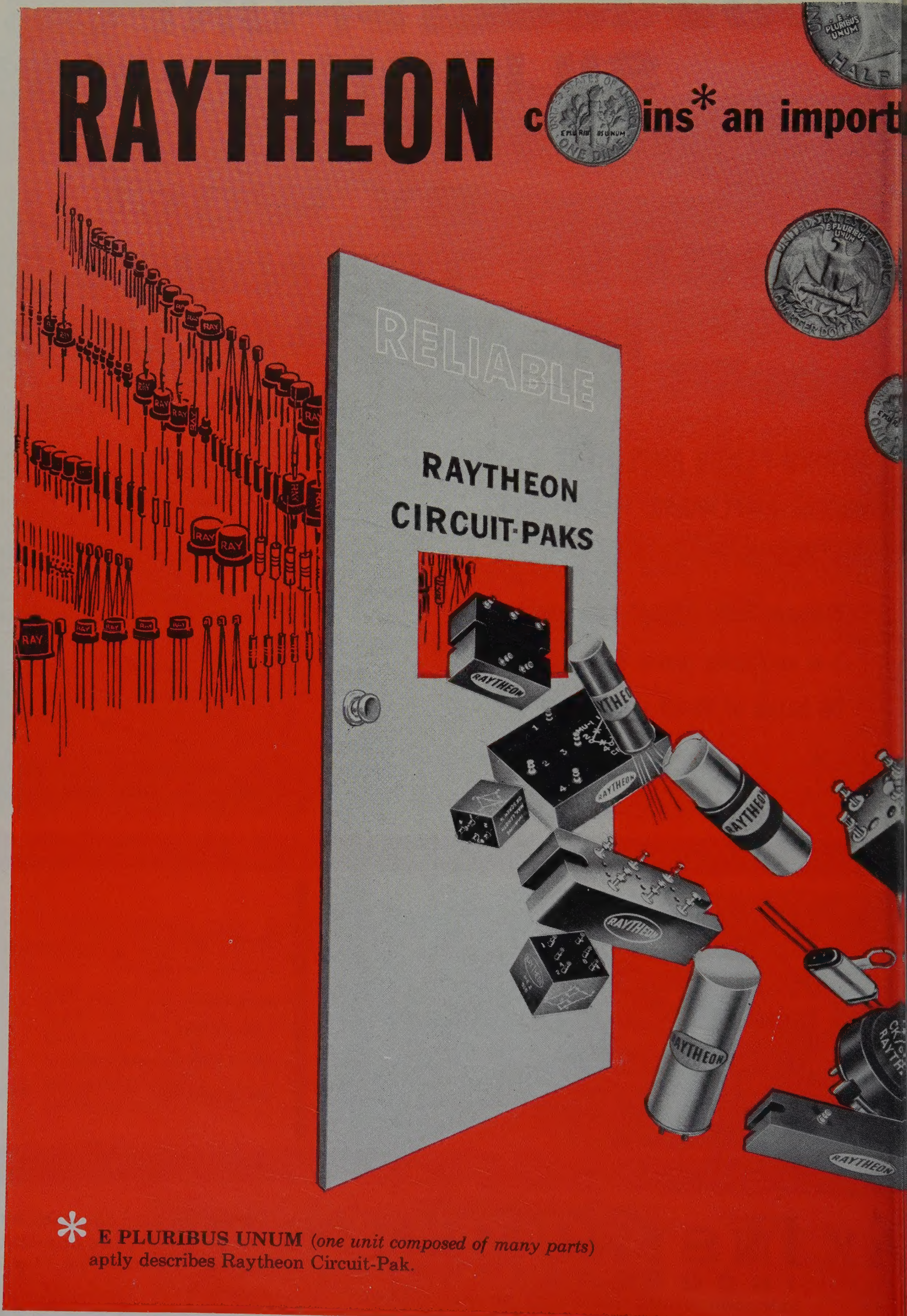

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SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

November 1959 Vol. 2 No. 11

Editorial 17

A Practical Approach to Transistor Circuit Design, *by James D. Long* 19

Counters Using Single Crystal Barium Titanate Capacitors, *by T. R. Hoffman* 24

A Report On The International Convention On Transistors And Associated Semiconductor Devices, *by Bernard Reich* 27

Variable Capacitance Diffused Junction Diodes, *by W. Macdonald, D. Schultz, and Dr. J. R. Madigan* 29

Solid State Physics at The National Bureau of Standards 34

Applications Engineering Digests 40

Semiconductor and Solid-State Bibliography 42

Patent Review 45

Characteristics Charts of New Transistors 56

Departments
- Book Reviews 14
- Market News 48
- New Products 50
- Industry News 60
- Personnel Notes 66
- New Literature 69

Advertisers' Index 72

Front Cover

Furnace used at the National Bureau of Standards to grow crystals by the Kyropolos technique. The coil surrounding the vacuum chamber provides a temperature sufficient to keep the metal in the small cup molten. As a seed crystal is removed very slowly from the melt, the metal adhering to it reaches the melting point and starts to solidify, forming a large single crystal.

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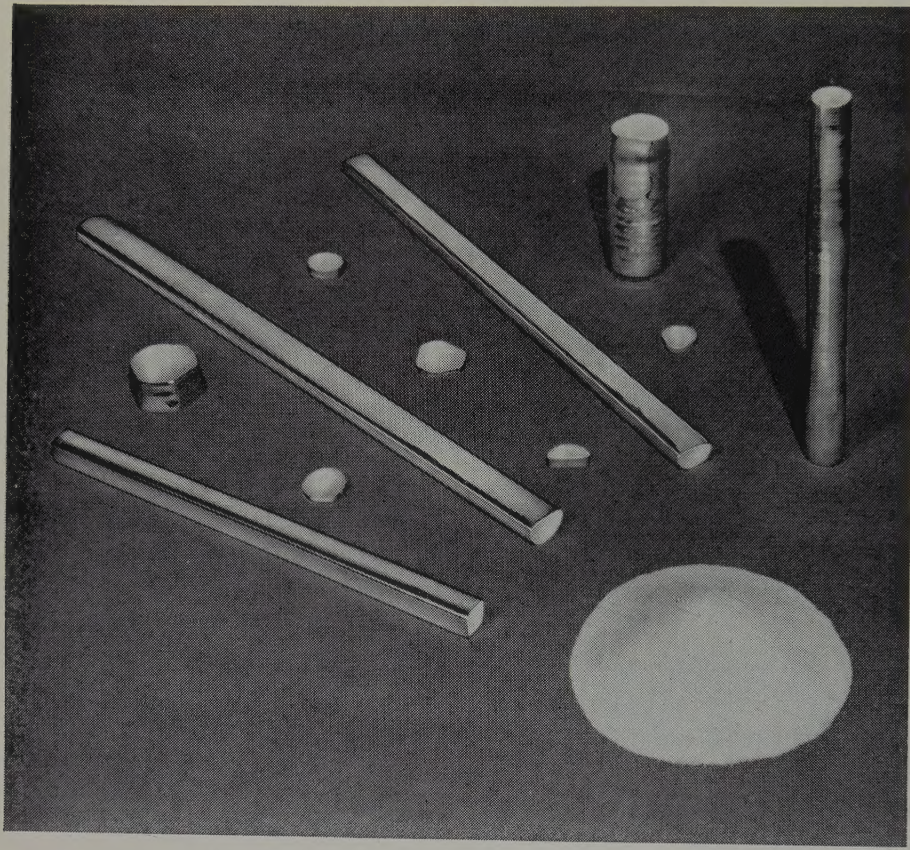

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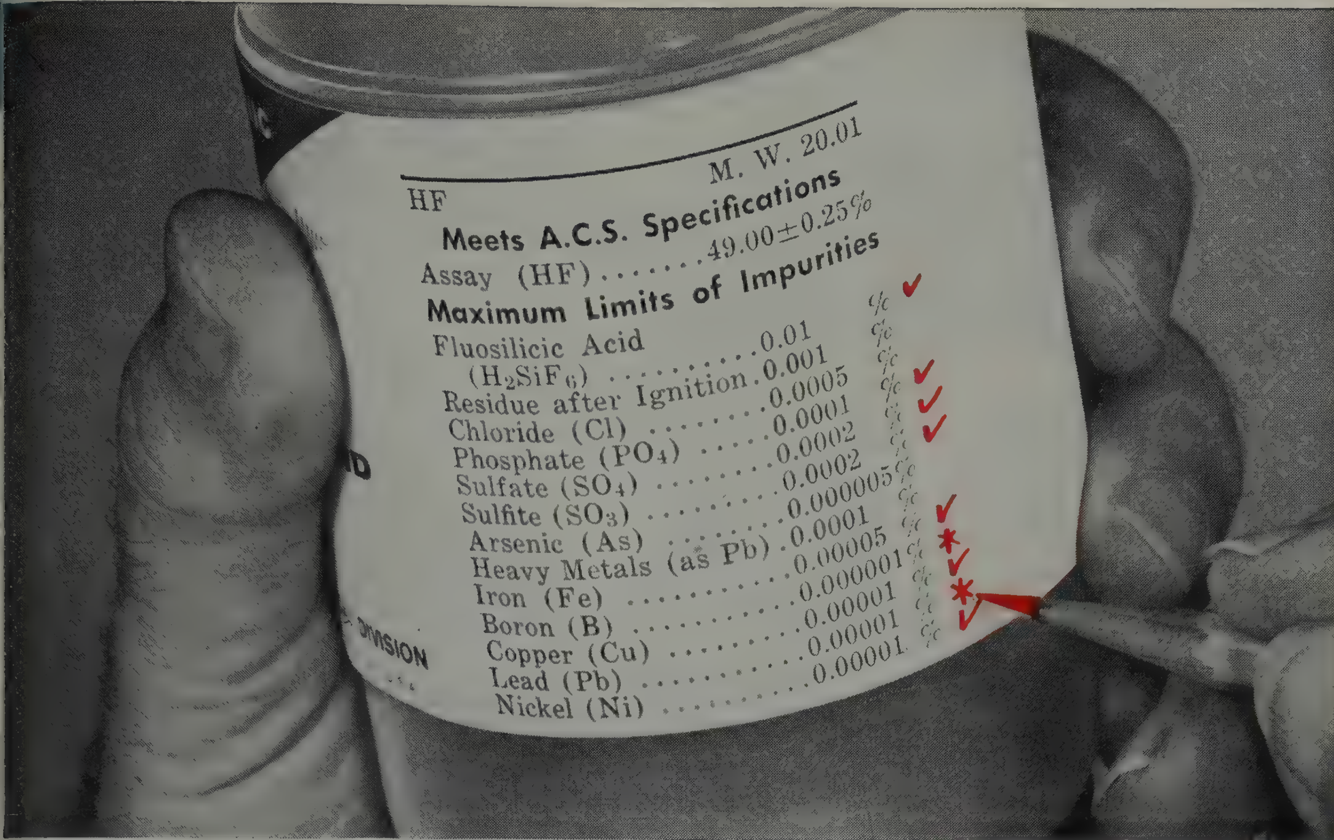

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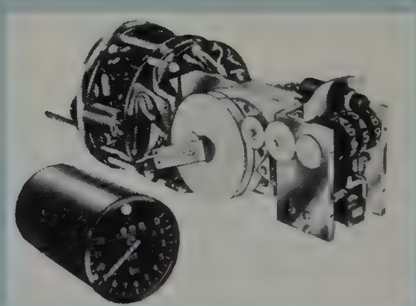

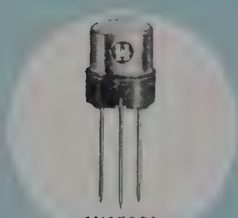

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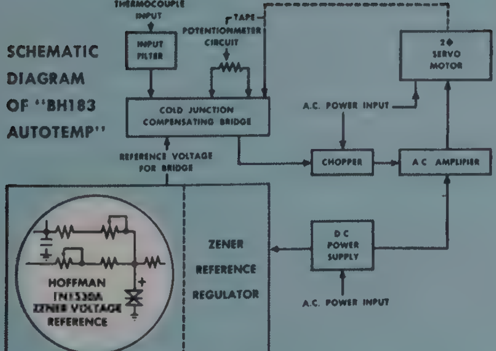

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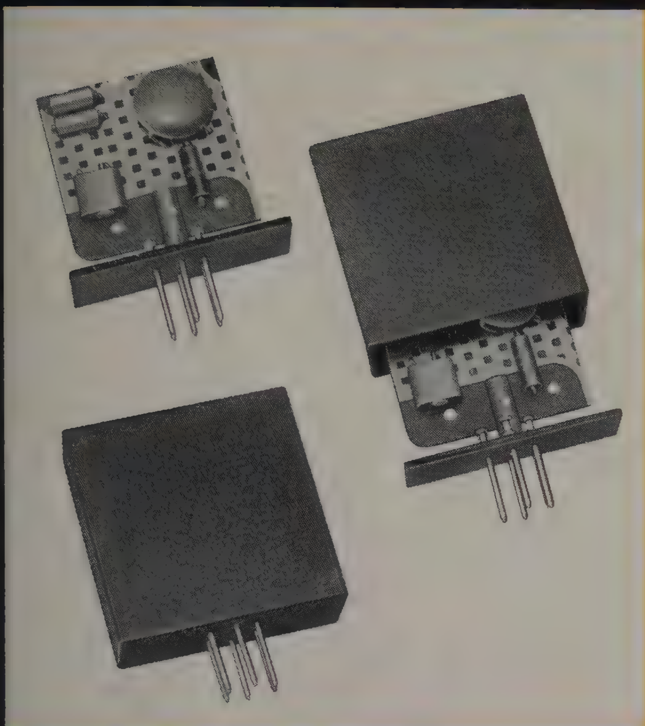

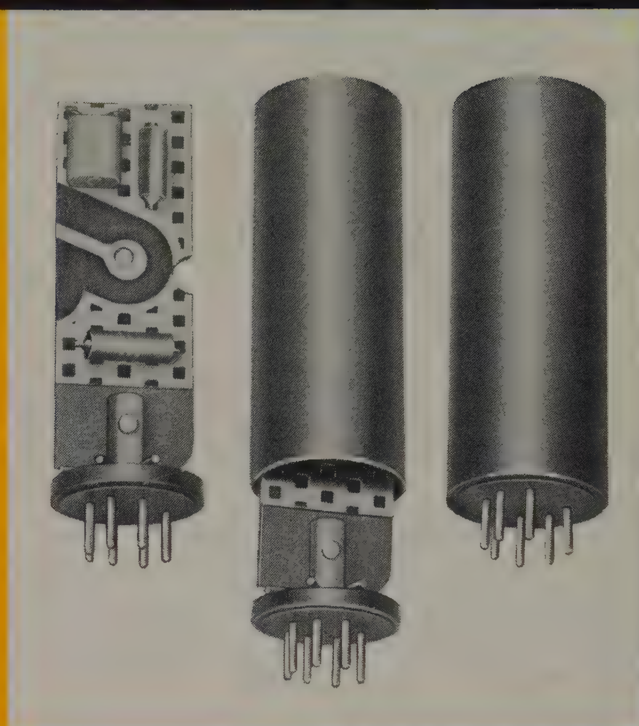

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BOOK REVIEWS . . .

TITLE: The Properties, Physics, and Design of Semiconductor Devices

AUTHOR: John N. Shive

PUBLISHER: D. Van Nostrand Company 1959

The Properties, Physics, and Design of Semiconductor Devices is another of the Bell Laboratories Technical Series. The book is divided into two distinct sections: The first dealing with the nature, properties and usage of semiconductor devices. The second with the physics of solids and consequent applications to the design of semiconductor devices.

The first three chapters introduce and discuss the semiconductor in terms of atomic properties. The effects of impurities on resistivity and conductivity are stressed, and rectification, photoelectric, and thermoelectric effects are considered.

Chapters III and IV comprise a basic textbook on the thermistor. This device is described in great detail starting with the fabrication and physical properties. The change of various electrical parameters with respect to temperature and time are defined, discussed, and graphically displayed, serving as an introduction to Chapter IV, which is devoted to uses of thermistors. Here may be found a veritable fund of information on thermometry, temperature compensation, *r-f* power measurement, and a wide variety of uses.

The varistor is treated in a like manner in Chapters V and VI, and as before a catalogue of uses of the varistor follows a very thorough presentation of its properties.

The balance of Part 1 of the book is concerned with photocells and the transistor. A historic presentation of the discovery of the transistor preceeds a discussion of the early point contact and more recent junction types. Actual circuit characterization is covered in a clear, though fairly elementary, manner in Chapter XI. The following chapters consider the high-frequency problem and miscellaneous transistor types and circuitry.

Part 2 of the book develops the solid state physics of semiconductors. Chapter XV builds the Band Theory of Solids or "energy level" concept from the Bohr model of the atom. The mechanism of conduction in solids is discussed in chapter XVI, leading to statistical study of the behavior of holes and electrons, in the following chapter. *P-* and *n-* type semiconductors are studied and application of the continuity equation for excess minority carrier concentration is made to show that an electrostatic field exists whenever there is a donor or acceptor gradient in a semiconductor. *P-N* junction theory follows next in Chapter XIX. The remainder of the book considers the diode and the junction triode transistor as an outgrowth of the *p-n* concepts. There are in addition, chapters on photoemission, thermoelectric and other effects in semiconductors, in addition to various selected topics.

The Properties, Physics, and Design of Semiconductor Devices is a comprehensive presentation of the field of semiconductors in a manner unusual for its clear inductive development. This book covers uncommon devices such as the thermistor and varistor in excellent detail and presents the transistor in terms of a strong theoretical and practical foundation, not often encountered in tutorial texts.

TITLE: Principles of Electronic Instruments

AUTHOR: Dr. Gordon R. Partridge

PUBLISHER: Prentice-Hall Englewood Cliffs, N.J.

Principles of Electronic Instruments is a book that explains how various electronic instruments work, in terms of both the theory of instrumentation and the actual operation of measuring circuits.

The measurement of voltage, because of its very basic relationship to other quantities, is treated in elaborate detail in chapters two to six. Here the peak detector is described and the various errors in output for various waveform inputs are defined. Circuitry of the *d-c* vacuum tube voltmeter is next covered. The cathode follower, bridge and *d-c* integrator types are analysed and typical configurations are illustrated. A complete chapter on Feedback (Chapter IV) proceeds a very excellent discussion of *a-c* electronic voltmeters. The unique circuit features of three familiar commercial instruments are analysed.

The next chapters deal with the measurement of other quantities by electronic means. Chapter VII is concerned with current electrometer techniques for measuring minute charges. Chapter VIII is a very thorough and interesting work on electronic wattmeters. Chapter IX outlines and define methods of frequency measurement including an ample discussion of the frequency counter.

The remainder of the book covers many additional topics. The measurement of phase, time, sound, and radioactivity are but a few of the quantities considered. In addition there are chapters on component testing and digital display.

Principles of Electronic Instruments is a particularly well written book which clearly explains the techniques involved in electronic measurement and the often uncommon circuitry used to implement these techniques. The scope of the material covered and the unusual clarity of the text recommend this book highly to laboratory personnel.

TITLE: Concise Dictionary of Science

AUTHOR: Frank Gaynor

PUBLISHER: Philosophical Library New York 1959

The Concise Dictionary of Science is a complete and up-to-date dictionary offering explanations of various terms, names and concepts in every conceivable field of science.

The value of a book of this nature lies in the accuracy and detail of the various definitions. In this respect the work is excellent. The definition of an element, for example, identifies the atomic number, atomic weight, melting and boiling points, state and various isotopes in addition to the density, date, discoverer and other pertinent information. Mathematical definitions are clearly illustrated by an example; electrical definitions are related to known quantities.

Concise Dictionary of Science is a valuable reference text useful in any course of scientific study, in addition to providing a ready collection of factual scientific information for the engineer.

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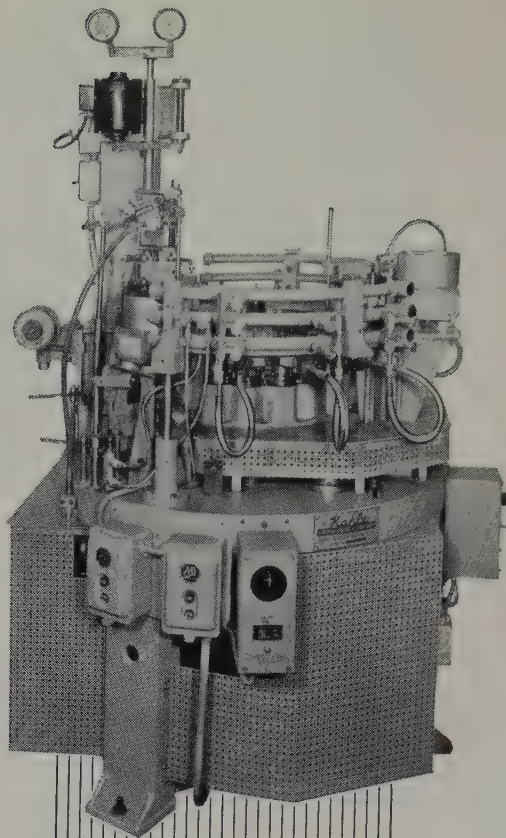

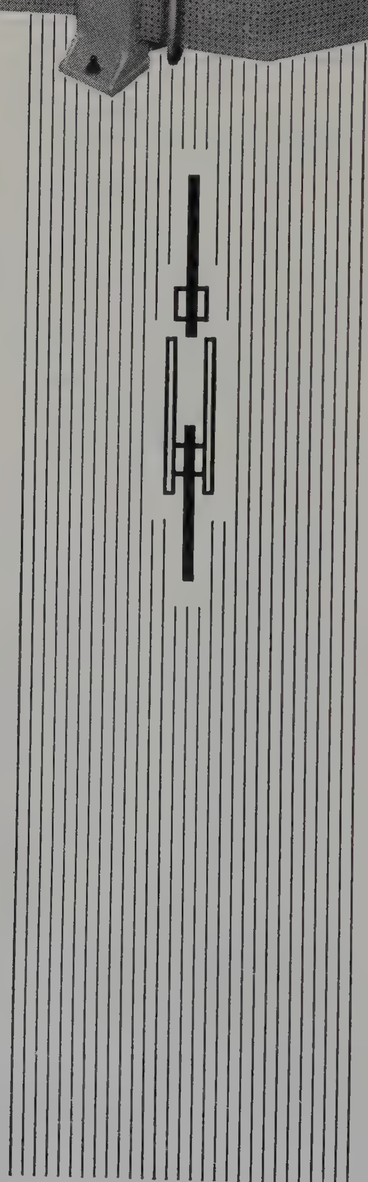

Editorial . . .

Tear Sheets

Beginning with this issue we're discontinuing our free tear sheet service for articles published in SCP. The response has been so enormous, we just can't keep up with it. We want to thank all those who requested tear-sheets for their interest, and for confirming to us how valuable the editorial content of our publication is to the engineers engaged in the electronic industry. Single copies of all issues may be purchased by those who wish copies of articles . . . better still, we suggest that you subscribe to our magazine if you aren't already doing so . . . then you'll never miss out on obtaining any of the articles you've shown us that you want. Thanks again!

Nuclear Radiation Effects Conference

On the 17 and 18 September 1959, the Second Conference on the Nuclear Radiation Effects on Semiconductor Devices Materials and Circuits sponsored by the Advisory Group on Electron Tubes was held in New York City. The purpose of this meeting was to brief scientists and engineers concerned with this problem on the latest technical findings.

The nuclear environment is one of the many environments in which semiconductor devices are expected to operate. It is no more or less important than the temperature power and mechanical environmental problems associated with the use of semiconductor devices. Therefore it behooves the engineer and scientist who designs and applies these devices to become informed on the problems associated with the application of these devices under the variety of environments including nuclear radiation.

Included in the highlights of the Second Conference was a summary paper on the present status of semiconductor devices in the nuclear environment as well as current report on new materials devices and circuits. In addition papers presented not only the deleterious effects of nuclear radiation on semiconductor devices but one worker utilized this effect as an instrument for detecting nuclear radiation.

We, of Semiconductor Products Magazine, have undertaken the task of reprinting and publishing the Proceedings of the Conference mainly as a service to semiconductor device engineers, circuit designers, and interested workers in the field. We feel that all designers of equipment utilizing semiconductor devices should be acquainted with the field and since very few texts are available on the subject the most expeditious medium of obtaining this information is through the Proceedings of the Conference. See page 49 for further information.

The Fifteenth National Electronics Conference

The fifteenth National Electronics Conference was held at Chicago October 14-16th. This Conference, which through the years has consistently maintained a very high level of scientific and technical achievements, has been the advanced Forum of the Nation for many new developments. This year papers were presented in the fields of servomechanisms, electron devices, electronic circuits, network theory, communications, computers, antennas, and radar navigation. Of particular interest for the field of solid state devices were the papers on design and performance of parametric amplifiers, and computer applications; advances in the technology of photovoltaic, Hall effect and photoconductive devices, the theory of semiconductor amplifiers and oscillators; and on the technology of microcircuits and molecular electronic devices.

The noise temperature of parametric amplifiers was shown to be reducible to values of the order of 100° K (noise temperature) with the use of gold bonded germanium diodes, and of the order of 35° K with the use of electron beam structures. In the latter case a special technique was suggested to extract noise from the beam. The frequency of operation of ferromagnetic parametric amplifiers was shown to extend to about 1 *kc* with the use of very thin films and correspondingly that of parametrons to about 30 *mc*. The latter devices were discussed in a previous Editorial (Oct. 1958).

As far as the varactor type parametric amplifiers are concerned, their performance depends upon the figure of merit of the variable capacitance diodes; i.e. on their Q factor, frequency of operation and capacitance voltage ratio. The matter of the optimization of the design of such varactors was discussed in detail.

Solar cells with theoretical conversion efficiencies up to 51%, instead of the present day 23.6% were predicted; these will be based on the use of multiple layer structures and compound semiconductors.

Extended long range communication links using scattering from a passive satellite sphere and receivers equipped with travelling wave solid state masers were shown to provide a hundredfold improvement in signal to noise ratio. The system noise may be reduced to a theoretical 7.5 k at 6 *kc*.

A number of papers dealt with the analysis and design of electronic circuits. For example a nonlinear analysis of transistor oscillators was developed, showing that the oscillator output and its harmonics could be predicted within a few percent. A new method of analysis of the stability of single and multiloop feedback amplifiers was presented, showing that the Nyquist plots of the input admittances could be obtained without actually solving the network determinant and using physically significant procedures of analysis.

The limiting power conditions which apply for the operation of transistor amplifiers in the avalanche mode were derived and shown to be lower than those for normal operation. The effect of the presence of the non-linear *p-n* junction capacitance on the pulse response of transistor amplifiers was investigated.

A field which appears very promising is that of molecular electron devices. This field encompasses those devices in which a complex interaction of various individual effects takes place. A simple example of realization was presented a few months ago with the construction of a semiconductor flip-flop obtained from a single block of germanium, in which resistive and capacitive paths were provided.

A new system capable of performing telemetry by means of the measurement of the intensity of a light beam was revealed. The system consists of a semiconductor block in which a saw-tooth oscillator is produced, having constant amplitude and having a frequency which varies with the intensity of the incident light.

Samuel L. Marshall

A Practical Approach To Transistor Circuit Design

JAMES D. LONG*

Approximate design equations are developed from the basic equivalent circuit of the transistor. It is indicated that junction transistor parameters vary with variations in emitter current and temperature. The variations which are important to a circuit designer are examined. In particular, the stability of the operating point in a Class A amplifier is discussed. An amplifier which is not stabilized for variations in temperature is compared to one that is stabilized. The input and output impedances, voltage gain, and operating point stability are calculated for the stabilized amplifier and compared to experimental results.

When the circuit designer turns for the first time to the use of the transistor, he may encounter more equations and variables than he has found in utilizing the vacuum tube. He would like to know how the variables behave and how he might use approximate but valid equations.

Approximate equations are developed here and applied to examples. These calculated results are then compared to experimental results. The following equivalent circuits and approximate formulas are valid at low frequencies, i.e., frequencies much less than the cut off frequency, f_α.

Common Base Configuration (Figs. 1 and 2)

For a black box such as depicted in *Fig. 2*, the voltage gain is given by:

$$A_v = \frac{E_o}{E_{in}} = \frac{I_L R_L}{I_{in} R_{in}}$$

If this general approach is applied to *Fig. 1*, the result is as follows:

$$E_o = \alpha \, i_e \, R_L$$

and

$$E_{in} = i_e r_e + (i_e - \alpha \, i_e) \, r_b$$
$$= i_e [r_e + (1-\alpha) \, r_b]$$

$$\text{Hence: } A_v = \frac{E_o}{E_{in}} = \frac{\alpha \, i_e R_L}{i_e [r_e + (1-\alpha) \, r_b]} = \frac{\alpha R_L}{r_e + (1-\alpha) \, r_b}$$

Letting $\beta = \dfrac{\alpha}{1-\alpha} \cong \dfrac{1}{1-\alpha}$, the voltage gain may be expressed as $A_v \cong \dfrac{\beta R_L}{r_b + \beta r_e}$

The input impedance is given by,

$$Z_{in} = \frac{E_{in}}{I_{in}} = \frac{i_e [r_e + (1-\alpha) \, r_b]}{i_e}$$

$$Z_{in} = r_e + (1-\alpha) \, r_b$$

The output impedance, Z_o, is approximately equal to r_c in parallel with the load resistor. If $r_c \gg R_L$, then

$$Z_o = \frac{r_c R_L}{r_c + R_L} \cong R_L$$

The current gain, A_i, is equal by examination to α.

$$A_i = \alpha$$

The power gain is equal to the voltage gain times the current gain.

$$A_p = (A_v)(A_i) = \frac{\alpha^2 R_L}{r_e + (1-\alpha) \, r_b}$$

If $\quad \alpha \cong 1, \quad A_p \cong \dfrac{\beta R_L}{r_b + \beta r_e}$

Common Emitter Configuration (Fig. 3)

The voltage gain in the common emitter circuit may be calculated as follows:

$$E_o = \left(\frac{\alpha}{1-\alpha}\right) i_b R_L$$

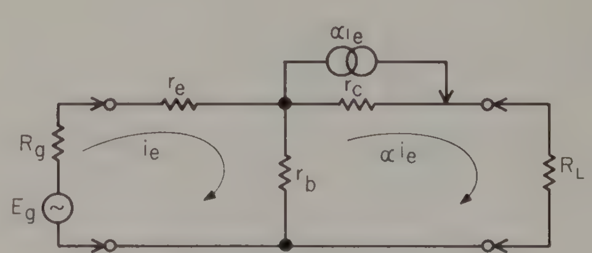

Fig. 1—Common base equivalent circuit.

Fig. 2—Black box representation of transistor circuit.

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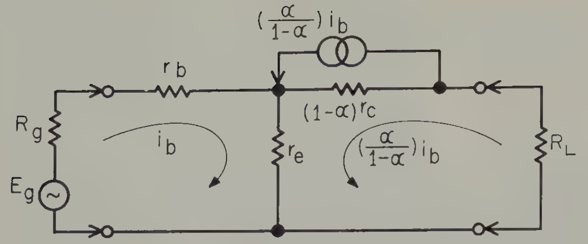


Fig. 3—Common emitter equivalent circuit.

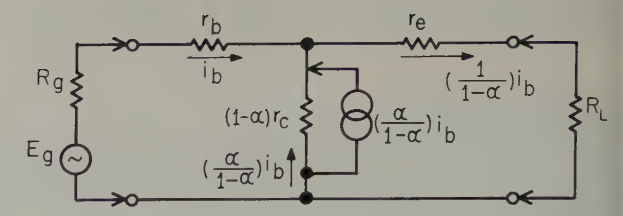


Fig. 4—Common collector equivalent circuit.

$$E_{in} = i_b\, r_b + \left(i_b + \frac{\alpha\, i_b}{1-\alpha}\right) r_e = i_b\left(r_b + \frac{r_e}{1-\alpha}\right)$$

$$A_v = \frac{E_o}{E_{in}} = \frac{\alpha\, R_L}{(1-\alpha)\left(r_b + \dfrac{r_e}{1-\alpha}\right)} \cong \frac{\beta\, R_L}{r_b + \beta\, r_e}$$

Note that the voltage gain of the common base stage is the same as that for the common emitter stage. However, as it will be seen, the output impedance of the common base stage is higher than that for the common emitter stage. In practice one can realize more voltage gain in the common emitter configuration because of the higher input impedance and lower output impedance of this type of stage.

The input impedance may be expressed as follows:

$$Z_{in} = \frac{E_{in}}{I_{in}} = \frac{i_b\left(r_b + \dfrac{r_e}{1-\alpha}\right)}{i_b}$$

Since $\quad \dfrac{1}{1-\alpha} \cong \beta, \quad Z_{in} \cong r_b + \beta\, r_e$

The approximate value of the output impedance is

$$Z_o \cong \frac{(1-\alpha)\, r_c\, R_L}{(1-\alpha)\, r_c + R_L} \cong \frac{r_c\, R_L}{r_c + \beta\, R_L}$$

The current gain is approximately equal to Beta.

$$A_i = \beta = \frac{\alpha}{1-\alpha}$$

The power gain is given by

$$A_p = (A_v)\,(A_i) = \left(\frac{\alpha\, R_L}{r_e + [1-\alpha]\, r_b}\right)\left(\frac{\alpha}{1-\alpha}\right)$$

$$A_p = \frac{\beta^2\, R_L}{r_b + \beta\, r_e}$$

Note that the power gain of the common emitter stage is approximately equal to Beta times the power gain of the common base stage.

Common Collector Configuration

The equivalent circuit of a transistor in the common collector configuration is shown in *Fig. 4*. The value of the resistance $(1-\alpha)\, r_c$ is usually large enough in comparison to the other parameters involved to be neglected. The gain calculations are as follows:

$$E_o = \frac{i_b\, R_L}{1-\alpha}$$

$$E_{in} = i_b\, r_b + \left(\frac{r_e + R_L}{1-\alpha}\right) i_b$$

Now one can assume that r_e is small in comparison to R_L and that $i_b\, r_b$ is much less than $\dfrac{R_L\, i_b}{1-\alpha}$.

Then $\quad E_{in} = E_o = \dfrac{i_b\, R_L}{1-\alpha}$

$$A_v = \frac{E_o}{E_{in}} = 1$$

$$A_i = \frac{1}{1-\alpha} \cong \beta$$

$$A_p = \frac{1}{1-\alpha} \cong \beta$$

$$Z_{in} = \frac{E_{in}}{I_{in}} = \frac{\dfrac{i_b\, R_L}{1-\alpha}}{i_b} \cong \beta\, R_L$$

The output impedance, Z_o, equals the open circuit voltage divided by the short circuit current.

$$E_{op} = E_g; \quad I_{sc} \cong \frac{i_b}{1-\alpha}$$

$$Z_o = \frac{E_{op}}{I_{sc}} = \frac{E_g}{\left(\dfrac{i_b}{1-\alpha}\right)} = \frac{E_g}{\beta\, i_b}$$

If $\quad R_g \gg r_b + \dfrac{r_e}{1-\alpha}, \quad \dfrac{E_g}{i_b} = R_g$

Then $\quad Z_o \cong \dfrac{R_g}{\beta}$

Variation of Transistor Parameters

Many junction transistor parameters vary with emitter current, temperature, age, and different samples of the same type of transistor. In order to apply the formulas

which were previously derived, it becomes necessary to know something about how transistor parameters vary.

The common emitter current gain, β, varies as shown in *Fig. 5*. Beta holds up much better with high values of I_e in the switching transistor than in the small signal transistor, so each type has its application.

The base to emitter voltage, V_{be}, varies in a linear fashion with changes in temperature, as shown in *Fig. 6*.

If the base to emitter voltage drop of a silicon transistor is .6 volts at 25 °C, at 125 °C it will be: 0.6V − (100) (.002) = 0.4 volts.

Ordinary diodes vary in much the same manner as the diodes in the transistor. Therefore, one is able at times to compensate a transistor against variations in V_{be} with variations in temperature by using one or more diodes.

The variation of the collector leakage current, I_{co}, with variation in temperature is in general a serious effect especially at high temperatures. The low voltage, room temperature value of I_{co} doubles for approximately every 10 °C rise in temperature.

$$(I_{co})_T = (I_{co})\left(2\right)^{\frac{\Delta T}{10}}$$

Where: $(I_{co})_T$ equals the value of I_{co} at the temperature T
I_{co} equals the low voltage, room temperature I_{co}
ΔT equals the change in temperature in degrees centigrade.

For example, if the I_{co} of a given transistor equals $1\mu A$ at 25 °C, it will equal $8\mu A$ at 55 °C.

$$(I_{co})_T = (1\mu A)\left(2\right)^{\frac{30}{10}} = (1\mu A)\ (8) = 8\mu A$$

One now is in a position to analyze the Class A amplifier. Two configurations will be considered, the unstabilized amplifier and one type of stabilized amplifier.

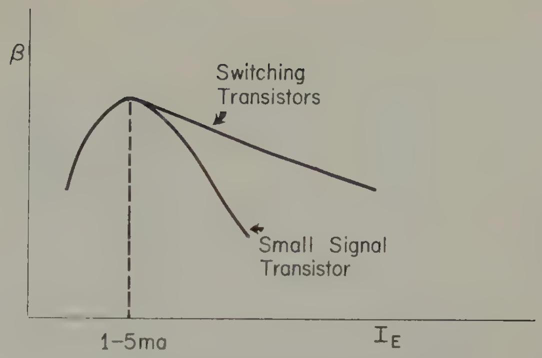


Fig. 5—Variation of Beta with I_E.

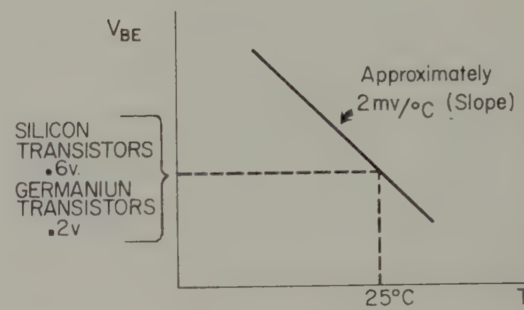


Fig. 6—Variation of V_{BE} with temperature.

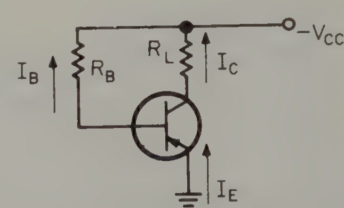


Fig. 7—Unstabilized amplifier circuit.

Unstabilized Amplifier

For the unstabilized amplifier illustrated in *Fig. 7*, the following conditions hold.

$$I_c = \alpha\, I_e + I_{co}$$

$$I_B = I_e - I_c = I_c\,\frac{(1-\alpha)}{\alpha} - \frac{I_{co}}{\alpha}$$

$$V_{cc} = I_c\, R_L + V_{cb} + V_{BE} = I_B\, R_B + V_{BE}$$

$$I_B R_B - I_c\, R_L - V_{CB} = 0$$

$$\left[I_c\left(\frac{1-\alpha}{\alpha}\right) - \frac{I_{co}}{\alpha}\right]R_B - I_c R_L - (V_{cc} - I_c R_L - V_{BE}) = 0$$

$$\left[I_c\left(\frac{1-\alpha}{\alpha}\right)\right]R_B - \left(\frac{I_{co}}{\alpha}\right)R_B - V_{cc} + V_{BE} = 0$$

$$\left[I_c\left(\frac{1-\alpha}{\alpha}\right)\right]R_B = V_{cc} + \frac{R_B\, I_{co}}{\alpha} - V_{BE}$$

$$I_c = \left(\frac{\alpha}{1-\alpha}\right)\left(\frac{V_{cc}}{R_B}\right) + \frac{I_{co}}{1-\alpha} - \left(\frac{\alpha}{1-\alpha}\right)\left(\frac{V_{BE}}{R_B}\right) \qquad (1)$$

If one takes the partial derivatives of Eq. 1, the variation of collector current with respect to variations of V_{cc}, I_{co}, and V_{BE} can be determined.

Two stability factors will be defined as follows:

$$S_c = \frac{\partial\, I_c}{\partial\, I_{co}} = \frac{\Delta\, I_c}{\Delta\, I_{co}}$$

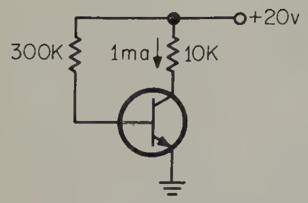
$$S'_c = \frac{\partial\, I_c}{\partial\, V_{BE}} = \frac{\Delta\, I_c}{\Delta\, V_{BE}}$$

For the configuration of *Fig. 7*:

$$S_c = \frac{\partial\, I_c}{\partial\, I_{co}} = \frac{1}{1-\alpha}\,;\ \Delta\, I_c \cong \beta\,\Delta\, I_{co}$$

$$S'_c = \frac{\partial\, I_c}{\partial\, V_{BE}} = -\left(\frac{\alpha}{1-\alpha}\right)\left(\frac{1}{R_B}\right);\ \Delta\, I_c = -\beta\,\frac{\Delta\, V_{BE}}{R_B}$$

The following is an illustrative example using the



GIVEN:
$I_{CO} = 1\mu a$ at 25° C
$\beta = 15$
$V_{BE} = .6v$ at 25°C
$I_C = 1ma$ at 25°C
$V_{CE} = 10v$ at 25°C
Max Temp = 85°C
$I_B = \frac{I_C}{\beta} = 67\ \mu a$
$R_B = \frac{V_{CC}}{I_B} = 300K$

Fig. 8—Data for illustrative problem. (Unstabilized amplifier.)

conditions outlined in *Fig. 8*. To find the operating point at $T = 85$ °C, we proceed as follows:

$$I_{co} \text{ at } 85\ ^\circ\text{C} = 1\mu A \left(2\right)^{\frac{60}{10}} = 64\mu A$$

$$\Delta I_{co} = 64\mu A - 1\mu A = 63\mu A$$

$$V_{BE} \text{ at } 85\ ^\circ\text{C} = .6\text{V} - (.002)\ (60) = .48 \text{ volts}$$

$$\Delta V_{BE} = -.12 \text{ volts}$$

$$(\Delta I_c) \text{ total} = \beta \Delta I_{co} - \beta \frac{\Delta V_{BE}}{R_B}$$

$$= (15)\ (63\mu A) - \left(\frac{15}{300\text{K}}\right)(-.12\text{V})$$

$$= .951\ mA$$

$$I_c \text{ at } 85\ ^\circ\text{C} = (I)_{25\ ^\circ C} + \Delta I_c$$

$$= 1\ mA + .951\ mA \cong 1.95\ mA$$

$$(V_{ce})_{85\ ^\circ C} = 20\text{V} - (1.95\ mA)\ (10\text{K}) = .5 \text{ volts}$$

$$\Delta V_{ce} = 10\text{V} - .5\text{V} = 9.5 \text{ volts}$$

One can readily see that this type of configuration is not very stable with variations in temperature.

Stabilized Amplifier

A more stable type amplifier will now be considered. The circuit is that shown in *Fig. 9*.

If one follows the same procedure outlined in the previous circuit, the following equation will result:

$$I_c = \frac{I_{co}\left(1 + \frac{R_e}{R1} + \frac{R_e}{R2}\right)}{(1-\alpha) + \frac{R_e}{R1} + \frac{R_e}{R2}} - \frac{\alpha\left(\frac{1}{R1} + \frac{1}{R2}\right) V_{BE}}{(1-\alpha) + \frac{R_e}{R1} + \frac{R_e}{R2}}$$

$$+ \frac{\alpha V_{cc}}{R1\left(1 - \alpha + \frac{R_e}{R1} + \frac{R_e}{R2}\right)} \qquad (2)$$

Let R_{eq} equal the parallel combination of $R1$ and $R2$

$$\frac{1}{R_{eq}} = \frac{1}{R1} + \frac{1}{R2}$$

$$S_c = \frac{\partial I_c}{\partial I_{co}}$$

$$= \frac{1 + \frac{R_e}{R_{eq}}}{1 - \alpha + \frac{R_e}{R_{eq}}}$$

$$\cong \frac{1 + \frac{R_e}{R_{eq}}}{\frac{R_e}{R_{eq}}} = 1 + \frac{R_{eq}}{R_e}$$

For the circuit of *Fig. 9*, $S_c = 1 + \frac{R_{eq}}{R_e}$

$$\Delta I_c = \Delta I_{co}\left(1 + \frac{R_{eq}}{R_e}\right)$$

$$S'_c = \frac{\partial I_c}{\partial V_{BE}}$$

$$= \frac{-\frac{\alpha}{R_{eq}}}{1 - \alpha + \frac{R_e}{R_{eq}}}$$

$$\cong -\frac{\alpha}{R_e}$$

$$\Delta I_c \cong -\Delta V_{BE}\left(\frac{\alpha}{R_e}\right)$$

The stability of this type amplifier will now be compared to the unstabilized amplifier. *Fig. 10* shows the circuit and component values. The same operating point is chosen for comparison value. Desirable stability factors generally range from 3 to 6 but may be whatever the designer feels is adequate for his application. In this case, a stability factor of 4 will be chosen.

$$S_c = 1 + \frac{R_{eq}}{R_e} = 4$$

R_e is chosen to be 2K because at the operating current of $1mA$ the voltage drop across R_e will be considerably larger than V_{BE} and yet small enough to allow a large signal swing at the collector.

$$S_c = 1 + \frac{R_{eq}}{2\text{K}} = 4;\ R_{eq} = 6\text{K}$$

$$\frac{1}{R_{eq}} = \frac{1}{R1} + \frac{1}{R2} = \frac{1}{6\text{K}}$$

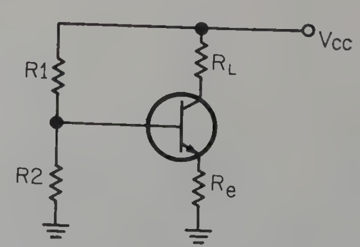


Fig. 9—Stabilized amplifier circuit.

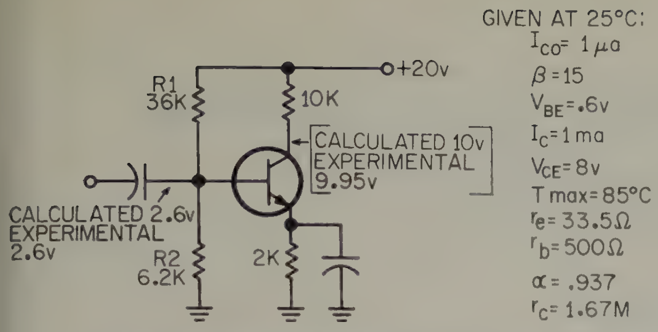


Fig. 10—Data for illustrative problem. (Stabilized amplifier.)

Since the value of S_c in general does not have to be exact, we can use a rule of thumb in the choice of the size of $R2$. Let $R2$ be the nearest commercially available size to R_{eq}. If $R2$ is chosen to be 6.2K, R_{eq} will be 6K or less which in turn will make $S_c \leqq 4$. Choose $R2$ equal to 6.2K and solve for $R1$ neglecting for the moment the effect of I_B flowing through $R1$. $R1$ will be referred to as $R1'$ while I_B is being neglected.

The voltage at the base of the transistor is equal to the base to emitter voltage plus the voltage drop across R_e.

$$V_B = V_{BE} + I_e R_e = 2.6 \text{ volts}$$

The voltage divider, $R1'$ and $R2$, must set the voltage at the base of the transistor at 2.6 volts.

$$\left(\frac{R2}{R1' + R2}\right) (20\text{V}) = 2.6\text{V}$$

$$\left(\frac{6.2\text{K}}{R1' + 6.2\text{K}}\right) (20\text{V}) = 2.6\text{V}$$

$$R1' = 41.5\text{K}$$

The divider composed of resistors $R1'$ and $R2$ would set the base of the transistor at 2.6 volts if it were not for the base current. Therefore, $R1$ must be smaller than $R1'$ to take into account the effect of the base current flowing through $R1$.

$$\frac{1}{R1} = \frac{1}{R1'} + \frac{1}{R_B}$$

where R_B is the base resistor which will set I_B to the correct value.

$$R_B = \frac{20\text{V} - 2.6\text{V}}{I_B} = \frac{17.4\text{V}}{I_c/\beta} = \frac{(17.4)\ (15)}{1\ mA} = 261\text{K}$$

$R1'$ has already been found to be 41.5K.

$$R1 = \frac{(41.5\text{K})\ (261\text{K})}{(41.5\text{K}) + (261\text{K})} \cong 36\text{K}$$

All of the resistor values have been determined, and one now can calculate the actual stability factor, S_c.

$$S_c = 1 + \frac{R_{eq}}{R_e} = 1 + \frac{\dfrac{(36\text{K})\ (6.2\text{K})}{42.2\text{K}}}{2\text{K}} = 3.65$$

The input impedance of the stage equals $r_b + \dfrac{r_e}{1 - \alpha}$.

$$Z_{in} = 500 + \frac{33.5}{.063} = 1030 \text{ ohm}$$

Experimental Result: 1200 ohm

The output impedance equals $(1 - \alpha)\ r_c$ in parallel with R_L.

$$Z_o = \frac{(105\text{K})\ (10\text{K})}{115\text{K}} \cong 9.2\text{K}$$

Experimental Result: 9.1K

The voltage gain equals $\dfrac{\alpha R_L}{r_e + r_b (1 - \alpha)}$

$$A_v = \frac{(.937)\ (10\text{K})}{33.5 + 500\ (.063)} = 144$$

Experimental Result: 118

The shift in operating point as the temperature changes from 25 °C to 85 °C will now be calculated. ΔI_{co} and ΔV_{BE} are the same as in the unstabilized amplifier.

$$\Delta I_{co} = 63\mu A;\ \Delta V_{BE} = -.12 \text{ volts}$$

$$(\Delta I_c)_1 = \Delta I_{co}\ (S_c) = (63\mu A)\ (3.65) = .23 mA$$

$$(\Delta I_c)_2 = \Delta V_{BE}\ (S'_c) = (-.12)\left(-\frac{\alpha}{R_e}\right) = .056\ mA$$

$$(\Delta I_c)_{total} = .23 + .056 = .286\ mA$$

Experimentally determined ΔI_c: .28 mA

$$(I_c)_{85\ °C} = 1 + .286 = 1.286\ mA$$

The operating point has shifted 2.86 volts compared to 9.5 volts for the unstabilized amplifier.

Summary

To summarize these design considerations, Table I gives the approximate formulas for voltage, current, and power gains and for the input and output impedances in the three transistor configurations.

The stability factors for the stabilized amplifier are:

$$S_c = \frac{\Delta I_c}{\Delta I_{co}} \cong 1 + \frac{R_{eq}}{R_e}$$

$$S'_c = \frac{\Delta I_c}{\Delta V_{BE}} \cong -\frac{\alpha}{R_e}$$

TABLE I

	COMMON BASE	COMMON EMITTER	COMMON COLLECTOR
A_v	$\frac{\beta R_L}{r_b + \beta r_e}$	$\frac{\beta R_L}{r_b + \beta r_e}$	1
A_i	α	β	β
A_p	$\frac{\beta R_L}{r_b + \beta r_e}$	$\frac{\beta^2 R_L}{r_b + \beta r_e}$	β
Z_{in}	$r_e + (1-\alpha) r_b$	$r_b + \beta r_e$	βR_L
Z_o	R_L	$\frac{r_c R_L}{r_c + \beta R_L}$	$\frac{R_g}{\beta}$

Counters Using Single Crystal Barium Titanate Capacitors

T. R. HOFFMAN*

A counting circuit of the "staircase" type employs a single-crystal barium titanate capacitor as the key element of the charging circuit and a silicon unijunction transistor as the discharge device. Count ratio can be varied from 1 to over 100, and is independent of input voltage amplitude over wide ranges. Sine waves can be applied directly to the charging circuit. No preliminary wave shaping is necessary.

IT IS FREQUENTLY NECESSARY to perform a counting process in electronic systems, and many counter circuits have been developed. One type is the "staircase" counter, in which a capacitor C is charged in step increments until the critical level of a discharge device is reached. C then discharges rapidly, generating a pulse that can be used to control subsequent actions, and the step-charging sequence repeats. Fig. 1 shows the block diagram of such a scheme. The input is assumed to be sinusoidal, although this is not in general a necessary condition. The specific action is that of frequency division, since each output pulse is occasioned by a predetermined number of input cycles. The number of input cycles per output pulse will be referred to in the ensuing sections as the "count ratio."

The design of vacuum-tube staircase counters has been described in detail.[1] This article presents a radically different approach, in which the charging circuit is a diode-gated single-crystal barium titanate capacitor and the discharge device is a silicon unijunction transistor. This arrangement has several advantages over previous mechanizations, namely:

(1) a sinusoidal input voltage may be applied directly to the barium titanate capacitor, thus avoiding the need for converting the input to square waves or pulses;
(2) count ratio is independent of input voltage amplitude over wide ranges;
(3) the increments of voltage across C are all the same height, so that high count ratios are as stable as low ones—count ratios in excess of 100 are readily obtainable in a single stage;
(4) the circuit is exceedingly simple—number of components is minimized.

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Sections I and II describe the single-crystal barium titanate capacitor and the unijunction transistor, respectively. Sections III and IV discuss their simultaneous use in the staircase counter. Section V considers possible applications briefly.

I. Single-Crystal Barium Titanate Capacitors

Barium titanate is a ferroelectric material. The dynamic charge *vs.* voltage plot (or "hysteresigram") is shown in *Fig. 2*. A and B represent the two remanent polarization states that can exist when the voltage is zero. The quantity "$2Q_R$" is called the "remanent charge switched." It is the charge that is dumped into the circuit external to the single-crystal

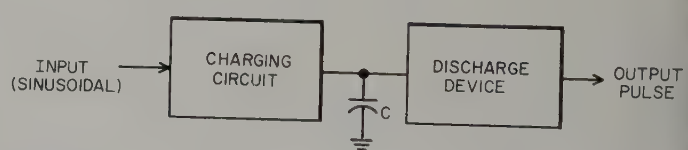

Fig. 1. Staircase counter

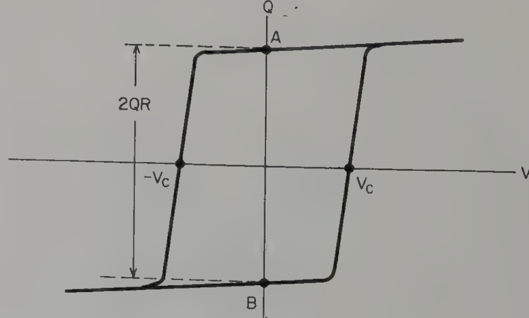

Fig. 2. Single crystal barium titanate hysteresigram

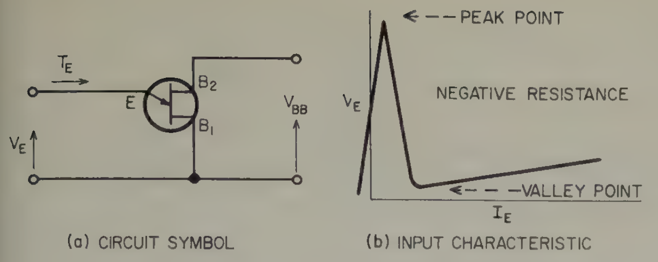

Fig. 3. Unijunction transistor

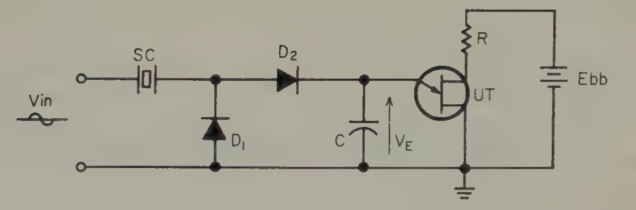

Fig. 4. Staircase counter circuit

unit when switching from A to B or vice versa occurs.

A voltage swing that exceeds the coercive voltage V_C in first one direction then the other will cause the unit to follow the hysteresis loop of *Fig. 2* in a counter clockwise direction. Current of appreciable magnitude will flow in the external circuit only during those intervals when the vertical portions of the loop are being traversed. At all other times the dynamic capacity dq/dc of the unit is very small, so that the capacitive reactance is very high.

II. The Unijunction Transistor

The unijunction transistor (or "double-base diode," as it was originally called) is a relative newcomer to the growing family of practical semiconductor devices. It is constructed by making two ohmic base contacts (base 1 and base 2) at opposite ends of a silicon bar, then adding a single rectifying contact (the emitter) part way down the bar. The operating characteristic of interest is the stable negative resistance that appears between emitter and base 1 under certain conditions. *Fig. 3* shows the circuit symbol and the input characteristic for a particular value of V_{BB}. As V_{BB} varies the curve retains the same general shape, but the peak point varies in direct proportion.

III. Staircase Counter Using a Single Crystal Barium Titanate Capacitor and a Unijunction Transistor

The basic staircase counter circuit using a single-crystal barium titanate capacitor in the charging circuit and a unijunction transistor as the discharge device is shown in *Fig. 4.* The input voltage is assumed to be sinusoidal, and large enough to switch the single-crystal capacitor SC back and forth between remanent charge points A and B of *Fig. 2*.

Operation may best be explained by assuming that initially C is uncharged and SC has just been set to point B by a negative half cycle of V_{in}. The next positive half cycle of V_{in} will switch SC to point A, delivering charge $2Q_R$ via diode D_2 to capacitor C in so doing. C will therefore receive a voltage increment $2Q_R/C$. The next negative half cycle of V_{in} will reset SC to B, with charge flow to ground via diode D_1. D_2 will be reverse-biased, hence C will not discharge appreciably and V_E will remain (ideally) at $2Q_R/C$.

Subsequent cycles of V_{in} will have the same effect. Each positive half cycle will switch SC to A and add a voltage increment. $2Q_R/C$ to V_E. Each negative half cycle resets SC to B, leaving V_E unchanged. This continues until the accumulated voltage increments across C cause V_E to exceed the peak point of the UT input characteristic. The UT input resistance then suddenly becomes negative and C is discharged very rapidly. V_E drops to zero, the UT input resistance becomes positive and high again, and the step-charging process repeats. A set of waveforms for a count ratio of 5 is shown in *Fig. 5*. The spike at UT base 2 is caused by current flow in the base 1—base 2 circuit at the moment of C discharge.

Count ratio can be varied by varying C, $2Q_R$, or E_{bb}. The first two possibilities vary the height of the increments, while the third changes the critical level of the discharge device.

IV. Experimental Results

Laboratory tests were made on the circuit of *Fig. 4*.

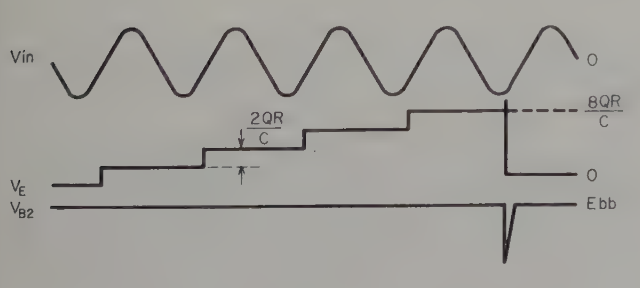

Fig. 5. Staircase counter waveforms

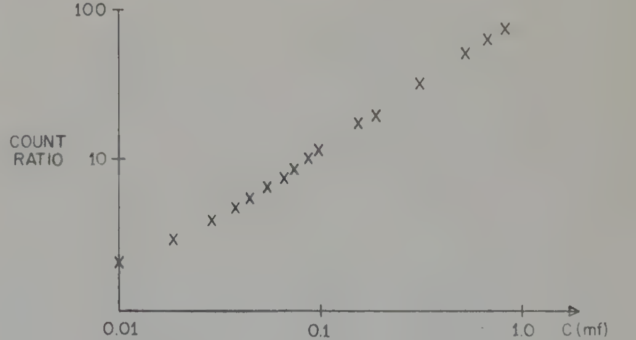

Fig. 6. Count Ratio *vs.* C

SC was a number 7 unit manufactured by the Harshaw Chemical Corporation. It had a nominal $2Q_R$ of 0.125 microcoulombs. D_1 and D_2 were Hughes Corporation type 6008 silicon diodes. C was a decade capacitor box variable from 0.01 to 1.0 microfarads. *UT* was a General Electric Company 2N490 silicon unijunction transistor.

(a) *Count Ratio vs. C*

Figure 6 shows a plot of Count Ratio *vs* C .The graph is shown as a series of points because of the discrete capacity steps used in making the test. Actually, there is a range of *C* for each count ratio, and the plot for all possible values of *C* would be a staircase similar to the V_E waveform of *Fig.* 5. The plot shows that count ratio increases linearly up to over 100. This linearity is due to the aforementioned equality of voltage increments, as contrasted with the exponential curve obtained with tube circuits.[1] In the latter case the height of each voltage increment depends on the voltage already accumulated, hence, each increment is smaller than its predecessor (unless additional circuitry is added to compensate).

If count ratios higher than those conveniently obtainable with a single stage are needed, it is possible to cascade counters to any desired degree.

(b) *Count Ratio vs.* E_{bb}

Variation of E_{bb} produces the curve of *Fig.* 7. As in the case of *C*, a range of E_{bb} exists for each count ratio. The only limitation here is imposed by the maximum allowable E_{bb} for the unijunction transistor used.

(c) *Effect of* V_{in} *Variation on Count Ratio*

Count ratio is independent of V_{in} over wide ranges, as shown by the data of Table I. $2Q_R$ increases slightly as V_{in} increases, hence, count ratio will be lowered one unit at some critical V_{in}. In case 1, where *C* is small so that the voltage increments are relatively large, there is a region of uncertainty between counts of 5 and 4 due to line voltage fluctuations. The uncertain area becomes smaller as C is increased. It was less than a volt in case 2.

(d) *Effect of Input Frequency on Count Ratio*

Input frequency is not a factor in count ratio until it becomes so high that the finite switching time of SC prevents attainment of full increment height, or so low that appreciable discharge of C occurs between charging intervals. The high frequency limit is a function of V_{in}, since this affects switching time. The low frequency limit depends on the leakage resistance of *C*, the back resistance of the diodes, and the unijunction transistor "off" input resistance. An "order of magnitude" estimate for usable range with ordinary components might be from 10 *cps* to 100 *kcps*.

The data of tests (a) and (b) was taken with an input frequency of 10 *kcps*. 400 *cps* was used in (c).

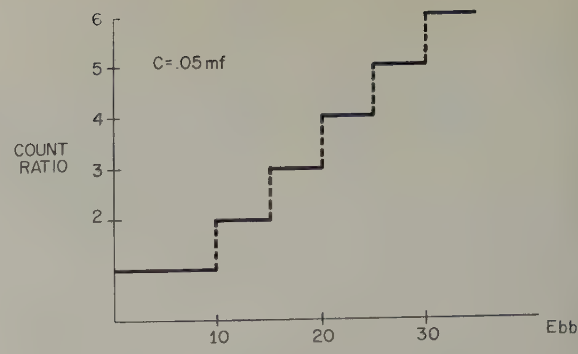

Fig. 7. Count Ratio *vs.* E_{bb}

V. Possible Areas of Application

Counters of the type described are well adapted for use as frequency dividers in systems such as loran (accurate time measurement), television (to derive frame rate from equalizer pulse rate) and radar (range marks). In conjunction with gating circuits, they can perform non-repetitive time interval measurements. Two counters plus associated gates can time sequentially repeating independently controlled intervals such as are required to control the "on" and "off" times of a seam welder. This principle can readily be extended to more than two intervals.

Use of staircase sweep voltages for electrostatic storage tubes enables accurate positioning of the electron beam, with sufficient time spent at each storage location to allow for read-out and subsequent regeneration if desired.

Modulation of E_{bb} can produce interesting effects. Pulse position modulation is a direct possibility. Analog-to-digital conversion occurs if the analog voltage is used for E_{bb} (with a *d-c* bias, if necessary, to insure that the net base 2 supply is always positive) and the resulting staircase waveform (with a number of steps proportional to instantaneous E_{bb}) is differentiated to produce pulses which set a flip-flop register to the appropriate digital number.

In summation, it is felt that virtually unlimited possibilities exist for these novel components. The retarding element to date has been the problem of questionable material stability. Progress has been made in this area, and applications of a type that require merely the existence of two stable remanent points now seem feasible.

Reference

[1] "Counter Circuits for Television," by Easton and Odessey; *Electronics*, May 1948.

TABLE I

	Vin	COUNT RATIO
(1) C=.05	0–15	–
	16–79	5
	91–135	4
(2) C=.15	0–15	–
	16–68	13
	69–135	12

A Report On The International Convention On Transistors And Associated Semiconductor Devices

BERNARD REICH*

THE INTERNATIONAL CONVENTION on Transistors and Associated Semiconductor Devices held at the Earls Court Exhibition Hall in London, England on 21-27 May 1959 appears to have been favorably received by both the technical personnel and by the public. This is apparent from the attendance at both the Convention and the Exhibition of approximately 2000 and 35,000 respectively. At the convention over 150 technical papers were presented covering five basically different areas of the semiconductor industry. The scope of the exhibition encompassed transistors and other semiconductor devices, materials used in transistor manufacture, equipment incorporating semiconductor devices and specialized components used in transistorized equipment.

Opening Session

The Convention, encompassing the five basic areas of the semiconductor industry, was opened by papers presented by Drs. J. Bardeen, W. H. Brattain and W. B. Shockley. The papers presented by the first two of these speakers were historical in nature presenting information on the developments leading to the discovery of the transistor and the years thereafter. Dr. Shockley's presentation concerned itself with transistor diode type devices and their application, a subject of great interest to him over the past few years.

Papers Presented

The papers presented during the remainder of the convention were oriented toward the following areas.

1. Materials. (Two Sessions)

In the initial session, lectures were presented on the following subjects: "Germanium and Silicon", "Auxiliary Materials in Transistor Technology" and "Properties and Application of Some Binary and Tertiary Semiconductor Components".

2. Basic Theory. (Two Sessions)

During the course of these sessions lectures were presented on the following topics: "Fundamentals of Junction Transistors", "A Modern Approach to Semiconductor and Vacuum Device Theory", "The Factors That Determine The High Frequency Performance of Transistors", "The Design Theory of Avalanche Injection Diodes".

3. Characteristics, Measurements and Transistors as a Circuit Element. (Five Sessions)

Lectures were presented on the following topics during these sessions: "Transistor Equivalent Circuits", "Shot Noise in Silicon Junction Diodes", "Characterization and Properties of Devices", "Radio Frequency Measurements on Transistors", "The Theory of Two Ports", "Avalanche Transistors as Fast Pulse Generators".

4. Technology and Design and Manufacture. (Four Sessions)

Lectures were presented on the following subjects: "Effect of Device Design on Performance and Quality", "The Evaluation of High Frequency Transistor Design", "Environmental and Device Cleanliness and Purity Standards", "Survey of Present Day Manufacturing Techniques of Transistors", "Trends in Transistor Manufacture Techniques", "Mechanization for Production of High Frequency Electro-Chemical Transistors".

5. Applications. (Nine Sessions)

Lecture papers on the following subjects were presented: "Domestic Radio Receivers and Frequency Equipment", "Line Communications Including Pulse Code Techniques", "Radio Communication", "Pulse Circuits", "Applications of Transistors in a Space Division Electronic Telephone System", "Transistors in Data Processing Machines", "The Use of Transistors in Instrumentation", "Industrial Applications of Silicon Controlled Rectifiers", "Rectification and Power Supplies",

*U. S. Army Signal Research and Development Laboratory, Ft. Monmouth, N. J.

"D.C. Amplifiers", "Applications of Photo Sensitive Devices".

From the breakdown of sessions it is evident that a wide area of the industry was covered with most of the sessions centering about device application. Generally, the areas of application covered were Switching Circuits, Communications, Linear Amplifiers and Oscillators, Instrumentation and Industrial Applications. It is evident that the Proceedings of this convention will take its place with the two *"Proceedings of the IRE"* set aside to semiconductors, November 1952 and June 1958 issues.

Publications

In addition to the papers presented at the Convention, three other publications appeared from the British Technical Literature which seemed to be of general overall interest to workers in the semiconductor field. These were:

1. "Transistors and Associated Semiconductor Devices". A Review of Progress by R. G. Hibbard Paper Nr 2914, May 1959—Institution of Electrical Engineers.

   In this article statistics on the growth of the semiconductor industry are presented since 1948. A brief summary of the techniques utilized in junction formation is given. Finally, mention is made of a few typical fields of application.
2. "World Trends in Semiconductor Development and Production" by C. C. Gee—June 1959 issue British Communications and Electronics. The article surveys contributions that different countries of the world have made to the development and production of semiconductor devices.
3. Finally, a special magazine prepared for the Exhibition entitled, "The Transistor Era" published by British Communications and Electronics.

   The primary aim of the publication is to provide a standard source of reference to products associated with the semiconductor industry, manufactured in the United Kingdom. In addition, a survey is also included of semiconductor manufacturers in other countries.

Exhibits

Exhibits were presented by firms manufacturing semiconductor devices, those making transistor materials, equipment incorporating transistors, and those manufacturing specialized components for use in transistorized equipment.

Some of the features noted at the Exhibit were:

1. Demonstrations of the automatic measurement of wafer thicknesses and other equipment associated with the manufacture of transistors by Newmarket Transistors Limited. By virtue of the practical aspects of this exhibit it attracted many visitors.
2. Silicon alloy transistors and Hall Effect Devices presented by Siemens and Halske, Germany.
3. Solid State circuitry incorporating transistors and diodes as well as passive elements of resistance and capacitance. One of the circuits shown was a multivibrator containing two diffused base transistors, two capacitors and eight resistors.

   In addition a gallium arsenide diode was shown which was reported to be capable of operating in the temperature range from −65°C to 325°C. These were noted at the Texas Instruments Limited Exhibit.
4. Controllable Silicon Rectifiers and Applications presented by Westinghouse Brake and Signal Limited. Various demonstrations were shown on the applications of this device.
5. A sensitive oscilloscope with frequency response extending from *d-c* to 300 *mc* with a screen size of 21 inches presented by the Atomic Energy Research Establishment.

At the present time there are nineteen companies in the United Kingdom either in the process of manufacture or about to manufacture semiconductor devices. Listed below are the manufacturers and general areas of operation.

Manufacturer	Transistors	Diodes and Rectifiers	Photo Sensitive Devices
Associated Electrical Industries		X	
*British Crystal Co Ltd	X	X	
Associated Transistors Ltd	X		
English Electric Valve Co Ltd		X	
The British Thomson Houston Co Ltd	X	X	X
Ferranti Ltd	X	X	X
General Electric Co Ltd	X	X	
*Intramural Rectifier Co G S Britain Ltd		X	X
Jos Lucas (Electrical) Ltd		X	
Mullard Ltd	X	X	X
Newmarket Transistors Ltd	X		
The Plessey Co Ltd		X	X
Rank Centel Ltd			X
*Semiconductor Ltd	X		
Siemens Edison Swan	X		
Standard Telephone & Cable Ltd	X	X	X
Technical Ceramics Ltd			X
*Texas Instruments Ltd	X	X	X
Westinghouse Brake and Signal Ltd		X	

*Companies having listed connections with United States manufacturers.

Variable Capacitance Diffused Junction Diodes

W. MacDONALD*   D. SCHULTZ*   DR. J. R. MADIGAN*

The space charge layer capacitance has been calculated for some impurity distributions which are characteristic of diffused junction devices. For an exponentially graded junction the capacitance-bias voltage relation varies continuously from the characteristic of a linearly graded to that of an abrupt junction as the ratio of the width of the barrier layer to the diffusion length is varied. The results indicate that the high capacitance to bias voltage change of an alloy diode can be achieved by a suitable diffusion program without sacrificing the other advantages of a diffused junction device.

THE VOLTAGE DEPENDENT CAPACITANCE of a semiconductor junction diode has recently been made the basis for a new type of capacitor by several manufacturers. An ideal alloy diode is characterized by an abrupt transition from n to p material and uniform impurity densities within the n and p regions. The cases of the abrupt and linear graded junctions have been treated by Shockley[1] while Giacoletto[2] has obtained an approximate expression for the space charge layer capacitance in more general types of graded junctions. However, Giacoletto's analysis assumes that the space charge layer extends into and grows only on one side of the junction. This is an inadequate model for diffused junction diodes. In solving Poisson's equation, it is possible to obtain a relatively simple expression for barrier layer capacitance as a function of bias voltage for impurity distributions which are characteristic of diffused junction devices, without the approximation given in the Shockley and Giacoletto papers, and with physically reasonable boundary conditions.

Calculation of Barrier Layer Capacitance

The particular form of the dependence of capacitance on bias voltage is a function of the distribution of impurities within the semiconductor. We have determined the transition region or space charge layer capacitance for the cases of abrupt, linear, exponential, and complementary error function distributions of impurities. The capacitances due to hole flow into the n-region and electron flow into the p-region have been neglected. Their effect would be to add two diffusion capacitances (one for holes and one for electrons) to the capacitance of the transition region. The diffusion capacitances have an exponential dependence on bias voltage[1] so that for the reverse bias conditions under which the diode will operate they are negligible compared to the transition region capacitance.

To determine the dependence of junction capacitance on bias voltage we must solve Poisson's equation

$$\frac{d^2V}{dx^2} = -\frac{\rho_{sc}}{\epsilon} \tag{1}$$

where V is the voltage, ρ_{sc} the space charge density, and ϵ is the permitivity of the material (e.g., silicon) subject to the boundary conditions. (See *Fig. 1*)

$$E(a) = E(c) = 0, \quad V(b) = 0$$

and

$$\int_a^b \rho_{sc}\, dx = -\int_b^c \rho_{sc}\, dx \tag{2}$$

The first condition states that the electric field (gradient of the potential) vanishes at the boundaries of the space charge layer ($x = a$ and $x = c$). The second states that the potential is zero at the junction ($x = b$). The last relationship states that the space charge region as a whole must be electrically neutral. That is, the total number of uncompensated acceptor atoms on the p-side of the junction must be balanced by an equal number of uncompensated donor atoms on the n-side of the junction.

Actually the boundary conditions are redundant, in the sense that the neutrality condition can be derived from the condition that the field vanishes at the limits of the space charge region. In addition it is not necessary to impose the condition that the potential be zero (i.e., change in sign) at the junction, in order to obtain either the maximum field or the voltage drop across the space charge layer. In the special cases that follow only the neutrality condition and the fact that the total width of the space charge layer, W, is equal to c-a have been applied.

Case 1. The Abrupt Junction

$\rho_{sc} = -qN_s$ for $a \leq x \leq b$ and $\rho_{sc} = qN_b$ for $b \leq x \leq c$

In this case the distribution of impurities is uniform within the n and p regions and there is an abrupt or step change in the distribution at the junction. The

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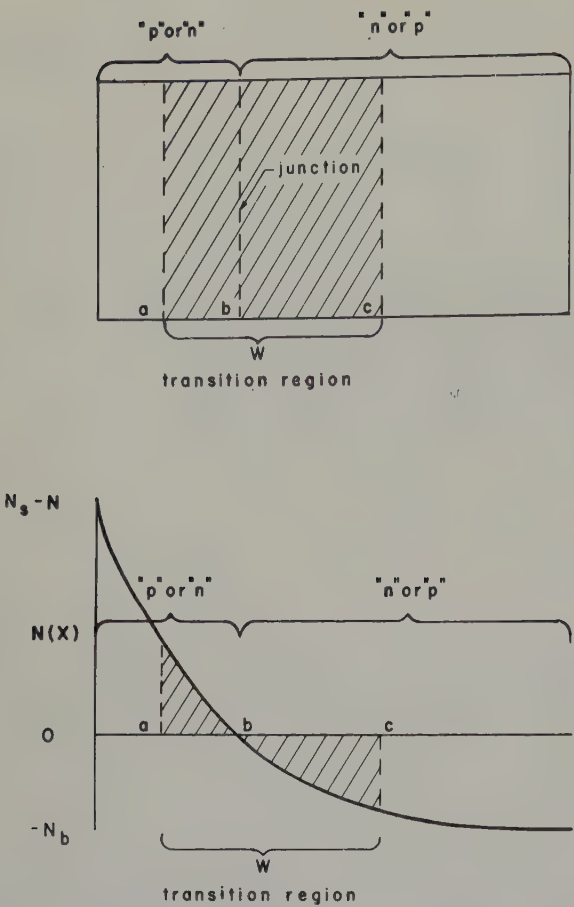

Fig. 1—Schematic diagram of a P-N junction (upper). Distribution of impurities within a P-N junction (lower).

junction voltage is related to the capacitance per unit area of the transition region (assuming that it may be treated as a parallel plate capacitor with $C_{sc} = \epsilon / W$* as follows

$$V = \frac{qW^2}{2\epsilon} \frac{N_b N_s}{N_b + N_s} = \frac{q\epsilon}{2C^2_{sc}} \frac{N_s N_b}{N_s + N_b} \tag{3}$$

where W is the width of the transition region, C_{sc} the capacitance per unit area of the transition region, N_s and N_b are the concentrations of the alloyed or diffused and base layer impurity atoms, respectively. For this model we have

$$VC^2 = \text{constant} \tag{4}$$

so that on a log-log plot of capacitance as a function of bias voltage we obtain a straight line of slope $-1/2$.

If $N_a \gg N_d$ as would be the case for an aluminum alloy junction, the expression reduces to

$$V = \frac{q\epsilon}{2C^2_{sc}} N_d = \frac{\epsilon}{2\mu_n\, C^2_{sc}} \frac{1}{\rho_b} \tag{5}$$

where ρ_b, the resistivity of base region is given by

$$\rho_b = q\mu_b N_b \tag{6}$$

The Q of such a capacitor is the ratio of the capacitive reactance to the series resistance of the diode. Since the series resistance in an alloy junction diode is determined principally by the resistance in the base layer the Q is given by

* See Appendix I

$$Q = \frac{1/\omega C_{sc}}{R_s} \propto \frac{\rho_b^{1/2}}{\rho_b} = \frac{1}{\rho_b^{1/2}} \tag{7}$$

So that a log-log plot of Q as a function of base layer resistivity at constant frequency and bias voltage should yield a straight line of slope $-1/2$.

Case 2. The Linear Graded Junction

$$\rho_{sc} = q\,\alpha\, x \text{ where } N_s - N_b = \alpha\, x$$

For this case the junction voltage is related to the capacitance by

$$V = \frac{\alpha q}{12\epsilon} W^3 = \frac{\alpha\, q\epsilon^2}{12} \frac{1}{C_{sc}^3} \tag{8}$$

On a log-log plot of capacitance as a function of bias voltage this model yields a straight line of slope $-1/3$. While this model does not correspond to a junction obtained either by alloying or diffusing into base material of uniform resistivity it is important in the sense that the properties of diffused junctions may be shown to lie between the extreme cases of the abrupt and the linear graded junctions (See *Fig. 2*).

The voltage capacitance relationship for this case indicates that for a fixed bias voltage the capacitance decreases with shallower gradients. This result is physically reasonable since shallower gradients require that the space charge layers extend more deeply into the *n*- and *p*-regions. The wider space charge layer reduces the equivalent parallel plate capacitance.

The capacitances, due to the exponential and complementary error function impurity distributions, have not previously been calculated (at least not in a form applicable to diffused junction devices). These distributions are of importance in the case of *p-n* junction produced by solid state diffusion techniques. The complementary error function is appropriate when diffusion takes place from an unlimited source and the decreasing exponential function applies to diffusion from a limited source[3]. *Fig. 1* shows the impurity distribution within a semiconductor for any arbitrary distribution of impurities. We assume that diffusion takes place from the surface ($x = 0$) into the body of the semiconductor which has an initial uniform impurity concentration N_b. The decreasing exponential and the complementary error function

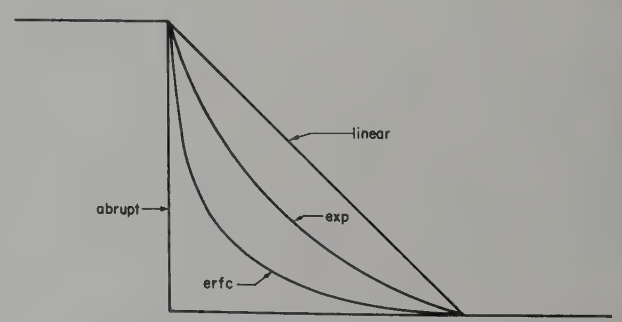

Fig. 2—Impurity distributions leading to various dependencies of junction voltage on capacitance.

distributions are similar in form but the complementary error function falls more rapidly with distance below the surface of the sample.

Case 3. The Decreasing Exponential Junction

$$N(x) = N_s \exp(-x/L) - N_b \text{ and } \rho_{sc} = qN(x)$$

where L is the diffusion length for the particular impurity atom which is being diffused in from the surface of the semiconductor. The junction voltage is related to the width of the space charge layer by

$$V = 2L\, E_D \frac{W}{2L}\left(\frac{W}{2L}\coth\frac{W}{2L} - 1\right) \qquad (9)$$

where $E_D = \frac{q}{\epsilon} N_b L$ is a field associated with the diffusion length and is therefore a function only of the time and temperature of the diffusion, the resistivity of the base material, and the permittivity of the semiconductor. If one defines a diffusion capacitance per unit area by the relation $C_D = \epsilon/L$ and the space charge layer capacitance by the relation $C_{sc} = \epsilon/W$, the capacitance voltage relationship becomes

$$V = 2q\epsilon N_b \frac{1}{C^2_D}\frac{C_D}{2C_{sc}}\left(\frac{C_D}{2C_{sc}}\coth\frac{C_D}{2C_{sc}} - 1\right) \qquad (10)$$

If one plots either $V/2LE_D$ as a function of $W/2L$ or $VC_D{}^2/2\,q\epsilon N_b$ as a function of $C_D/2C_{sc}$ on log-log paper one obtains the curve shown in *Fig. 3*. If the expressions for the abrupt and the linear graded junctions were plotted in the same way (i.e., voltage as a function of capacitance) their slopes would have been two and three, respectively. Therefore, if the exponentially graded junction lies between the abrupt and the linearly graded junctions as *Fig. 2* indicates, the slope of the curve should be between two and three. The slope of the capacitance-voltage curve for the exponential case varies continuously from three for small values to two for large values of $C_D/2C_{sc}$. The limiting cases can be shown to be

$$\frac{VC^2_D}{2qCN_b} = \frac{(C_D/2C_{sc})^3/3}{1-(C_D/2C_{sc})/3} = (C_D/2C_{sc})^3/3 \qquad \text{for } C_D/2C_{sc} \ll 1 \quad (11)$$

and

$$\frac{VC^2_D}{2q\epsilon N_b} = \left(\frac{C_D}{2C_{sc}}\right)^2 - \frac{C_D}{2C_{sc}} = \left(\frac{C_D}{2C_{sc}}\right)^2 \qquad \text{for } C_D/2C_{sc} \gg 1 \quad (12)$$

The dependence on the resistivity of the base material may be introduced by setting $\rho_b = q\mu_b N_b$. One can then in principle determine the dependence of the space charge layer capacitance on the resistivity of the base material for a fixed bias and a given diffusion program. This result may be used to determine the behavior of Q as a function of the base layer resistivity as was done for the abrupt case. However, the expression is transcendental and requires rather tedious numerical work and will not be pursued further.

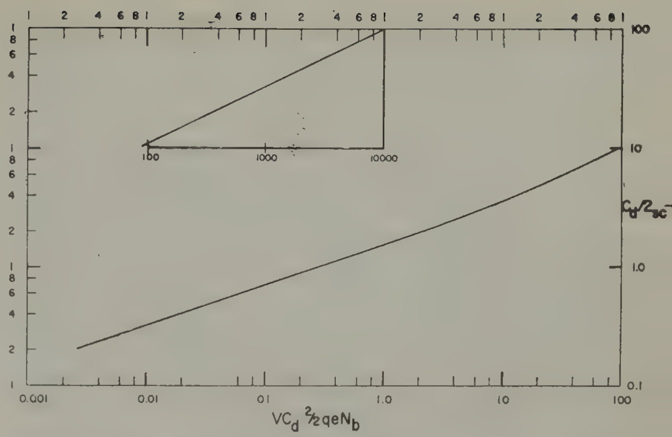

Fig. 3—Dependence of capacitance on bias voltage for the exponentially graded junction.

Case 4. The Complementary Error Function Graded Junction

$$\rho_{sc} = qN(x) = q(N_s \operatorname{erfc} x/L - N_b)$$

where L is the diffusion length for the particular impurity atom which is being diffused in from the surface, N_s is the constant (in time) surface concentration of this impurity, and N_b is the uniform concentration of the base layer impurity atom. In this case the junction voltage is related to the width of the space charge layer by

$$V = \frac{L}{2} E_D \left\{\left(\operatorname{erfc}\frac{a}{L} - \operatorname{erfc}\frac{c}{L}\right) - \frac{W}{L}\frac{2}{\sqrt{\pi}} e^{-x_j{}^2/L^2} - \frac{W}{L}\frac{E_M}{E_D}\right\} \qquad (13)$$

where $E_D = qN_sL/2\epsilon$ is the diffusion field and E_M/E_D, the ratio of field at the junction to the diffusion field, is given by

$$\frac{E_M}{E_D} = \left(\frac{2}{\sqrt{\pi}} e^{-c^2/L^2} - 2\frac{c}{L}\operatorname{erfc}\frac{c}{L}\right) - \left(\frac{2}{\sqrt{\pi}} e^{-x_j{}^2/L^2} - 2\frac{c}{L}\operatorname{erfc}\frac{x_j}{L}\right) \qquad (14)$$

For relatively long diffusions into high resistivity base material and/or large reverse biases c will be much greater than L and the junction voltage relation becomes to a high order of approximation

$$V = \frac{L}{2} E_D \left\{\operatorname{erfc}\frac{a}{L} - 2\frac{W}{L}\frac{c}{L}\frac{N_b}{N_s}\right\} \qquad (15)$$

where use has been made of the fact that the junction is defined as the place where the net space charge density vanishes.

Unfortunately all of the above expressions contain in some manner the boundaries, a and c, of the space charge layer. We have not been successful in obtaining an expression for voltage drop across the junction which depends only on the width of the space charge layer, w, the concentrations of the diffusing and base layer impurities, N_s and N_b respectively and the diffusion

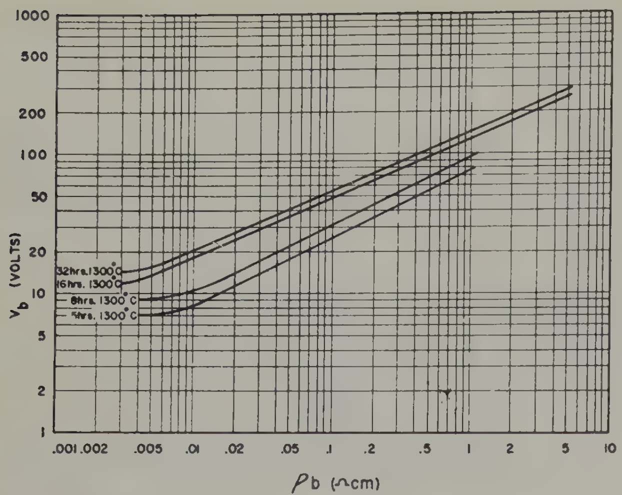

Fig. 4—Breakdown voltage measured at a reverse current of 10 mA as a function of base layer resistivity for a fixed diffusion program.

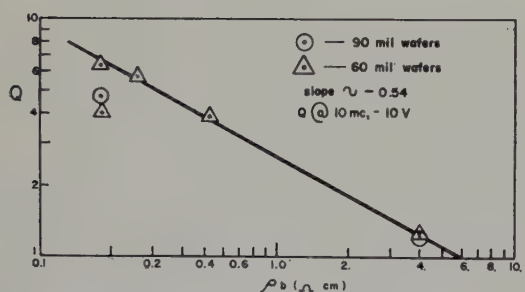

Fig. 5—Dependence of Q on base layer resistivity for some diffused junction diodes.

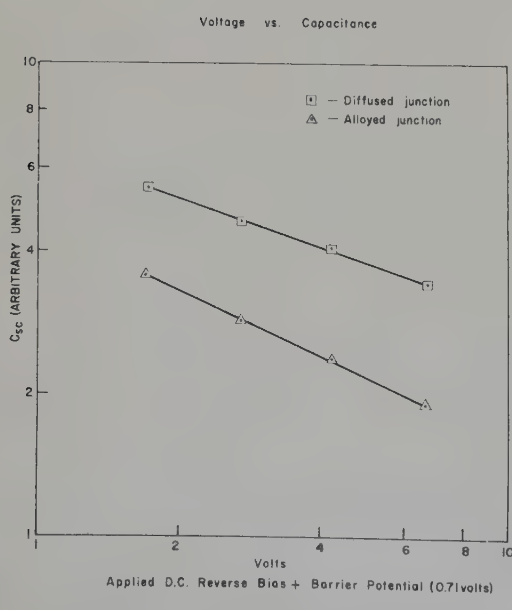

Fig. 6—Capacitance as a function of bias voltage for typical diffused alloy junction silicon diodes.

length, L, of the diffusing impurity atom. However, this does not prevent us from making some general observations about the capacitance associated with the complementary error function junction. This function leads to an impurity distribution that for similar conditions lies between the abrupt and exponential distribution (See *Fig. 2.*) It must therefore, have a voltage-capacitance relationship somewhere between the square and cubic dependence of voltage on capacitance of the abrupt and linear graded junctions, respectively.

Experimental Results

To test the theoretical predictions measurements were made of capacitance as a function of bias voltage at a fixed frequency and as a function of frequency at fixed bias voltage on both alloy and diffused junction silicon diodes. The dependence of Q on base layer resistivity may be easily determined from the Hoffman line of diffused zener regulators. The zener voltage of these units (measured at a zener current of 10 mA) as a function of base layer resistivity for a fixed diffusion program (i.e., a given diffusion time and temperature) is shown in *Fig. 4*. Measurements of Q for regulators of different nominal zener voltage are therefore easily transformed into plots of Q as a function of base layer resistivity. These results are presented in *Fig. 5* for 90 and 60 mil diameter diffused regulator wafers. The slope of -0.54 is approximately the value predicted by Eq. (7) for abrupt junctions. Since the capacitive reactance and the series resistance both vary inversely with area, their ratio Q should be independent of area and the points corresponding to the 90 and 60 mil diffused wafers should all fall on the same line. This is not the case for the lower voltage diodes plotted in *Fig. 5*. These units had high leakage current and the excessive leakage may account for the dependence of Q on area. If one represents the diode by an equivalent circuit consisting of a resistance, R_s in series with a resistance r_p, and a capacitance C, in parallel, the equivalent impedance of the diode is

$$Z = R_s + \frac{r_p}{1 + \omega^2 r_p{}^2 C^2} - j\,\frac{\omega r_p{}^2 C}{1 + \omega^2 r_p{}^2 C^2} \tag{16}$$

The Q of the circuit is the ratio of the reactive to resistive components of the impedance and may be expressed in the form

$$Q = \frac{1}{\dfrac{1 + R_s/r_p}{\omega r_p C} + \omega R_s C} \tag{17}$$

This differs from Eq. (7) by the addition of the term $(1 + R_s/r_p)/\omega r_p C$. Now R_s represents the base layer resistance of the diode and is usually small compared with r_p which is the equivalent barrier layer resistance shunted by a surface leakage resistance. To a high order of approximation Q is therefore given by

$$Q = \frac{1}{\dfrac{1}{\omega r_p C} + \omega R_s C}$$

All of these terms would be independent of area if the

value of r_p was not so strongly dependent on surface leakage. The surface leakage take places over the surface of a cylinder of area $2\pi rw$ where r is the radius of the junction and w is the width of the space charge layer. The capacitance on the other hand is directly proportional to πr^2. Thus at low frequencies where the first term in the denominator of Eq. (17) predominates Q will be directly proportional to r. This effect will only be observable (if it exists) at low frequencies and for diodes with high leakage currents (i.e., small values of r_p).

The capacitance-voltage curves plotted in *Fig. 6* show that the alloyed units have a square root dependence and the diffused units a dependence between the square and cube root, dependencies of capacitance on bias voltage associated with the abrupt and linear graded junctions. Diffused junction diodes should show the cube root dependence for relatively long diffusions into low resistivity material at small reverse bias and the square root dependence for relatively short diffusions into high resistivity material at large reverse bias voltages. These conclusions are confirmed by the data presented in *Fig. 7*.

In order to produce high Q diodes the series resistance must be made as small as possible. Since Q has been shown to be independent of the area of the junction, this can be achieved by lowering the resistivity of the base material and reducing the length of the series resistive path.

Discussion of Results

The behavior of both the alloy and diffused junction diodes studied is in good agreement with the theoretical predictions. The type of diode that one should use will depend upon the application. For instance one might wish to use the voltage dependent capacitance of a junction diode for the tuning capacitor in a broadcast band radio. For this application it is important to obtain the largest possible change in capacitance for a given change in the bias voltage. The fractional change in resonant frequency of an LC circuit for a given change in capacitance (assuming L fixed), is

$$\frac{\Delta\nu}{V} = -\frac{\Delta C}{2C} \qquad (18)$$

The relationship between the fractional change in capacitance and the fractional change in junction voltage is determined by the distribution of impurities within the semiconductor. From Equations (4) and (7) these relationships are

$$\frac{\Delta C}{C} = \frac{1}{2}\frac{\Delta V}{V} \quad \text{and} \quad \frac{\Delta C}{C} = \frac{1}{3}\frac{\Delta V}{V} \qquad (19)$$

for the abrupt and linear graded junctions, respectively.

The corresponding relationships between junction voltage and frequency are $V \propto \nu^4$ for the abrupt and $V \propto \nu^6$ for the linear graded junctions. Thus for a three to one change in frequency (to cover the broadcast band) there must be an eighty one to one change for the abrupt and a seven hundred and twenty-nine to one change for linear graded junction in bias voltage.

Since a diffused junction diode will be somewhere between these two limits, it would appear that an alloy junction which closely approximates the abrupt case would be most suitable for this application. However, *Fig. 7* indicates that by suitably adjusting the diffusion program one can obtain essentially the same capacitance-bias voltage dependence as an alloy junction. It, therefore appears that diffused junction diodes can be made which compare favorably with alloy diodes as far as their dependence of capacitance upon bias voltage is concerned and that the diffused narrow base diode can operate at much higher frequencies because of its lower and better controlled series resistance.

Of course one can obtain a very large change of capacitance with bias voltage if one is willing to operate in the forward bias region. Here the diffusion capacitance is the dominant term and there is an exponential dependence of the capacitance on bias voltage. If the forward current becomes appreciable the capacitive reactance decreases and finally becomes inductive.[4] One can avoid this condition by operating, in the case of silicon junctions, below about 0.4 of a volt.

Appendix

The distribution of impurities within the base region of a semiconductor of uniform impurity density N_b, assuming a surface impurity concentration N_s which falls off with depth below the surface according to the law $N_s f(x)$ is given by

$$N(x) = N_s f(x) - N_b \qquad (20)$$

The junction will be defined to be the point at which the net space charge density vanishes. That is, where

$$\rho_{sc} = qN(x_j) = 0 \qquad (21)$$

with x_j the depth of the junction below the surface. This definition requires that at the junction $f(x_j) = N_b/N_s$.

Poisson's equation shows that the maximum electric field occurs when

$$\frac{dE}{dx} = -\frac{d^2V}{dx^2} = \frac{\rho_{sc}}{\epsilon} = 0 \qquad (22)$$

This corresponds to $f(x) = N_b/N_s$ and consequently from the above definition of junction depth the maximum electric field occurs at the junction. Since the field essentially vanishes outside the space charge layer it will appear somewhat as shown in *Fig. 8*. The nonsymmetrical distribution of the field about its maximum value is due to the fact that the charge density must initially be lower in the base than at the surface for a junction to form. The requirement of overall charge neutrality for the space charge layer then requires that it extend more deeply on the side of lower impurity density.

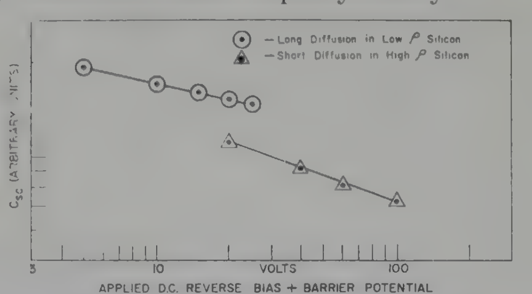

Fig. 7—Dependence of capacitance on bias voltage for two limiting diffusion programs.

The capacitance per unit area of the space charge layer is given by

$$C = Q/V_c - V_a = \frac{\epsilon \int_a^{x_j} \rho_{sc}\, dx}{\int_a^c E(x)dx} = \frac{\epsilon \int_a^{x_j} \frac{dE}{dx} dx}{\int_a^c E(x)dx} = \frac{\epsilon\, E(x_j)}{w\, E(x')}$$

where Q is the total charge in the space charge layer on either side of the junction, $V_c - V_a$ is the voltage drop across the space charge layer, a and c are the boundaries of the space charge region and x' is some value of x between a and c such that $wE(x') = \int_a^c E(x)dx$. Now $wE(x')$ is the area under the $E(x)$ curve of *Fig. 8*. It will be equal to $wE(x_j)$ if E is constant, but this is impossible since constant E implies $dE/dx = 0$ or $\rho_{sc} = 0$ which is contrary to the assumption of a finite space charge layer. Therefore, $wE(x_j)$ provides an upper limit to the area under the $E(x)$ curve and in general $E(x_j)/E(x')$ must be less than unity so that $C_{sc} > \epsilon/w$. The assumption made in the article that the space charge layer capacitance per unit area is equal to ϵ/W is, therefore, not strictly correct. For the impurity distributions considered the abrupt and the linear graded junctions form limiting cases and for these distributions the space charge layer capacitance per unit area is $2\epsilon/W$ and $3\epsilon/2W$, respectively. The actual space charge layer capacitance will therefore be from 1.5 to 2 times the value assumed in the article.

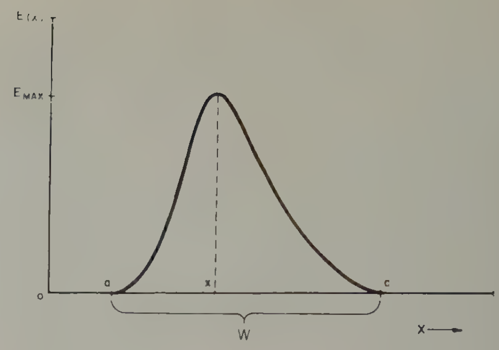

Fig. 8—The electric field within the semiconductor diode as a function of depth below the surface.

References

[1] W. Shockley, *BSTJ 28*, 435 (1949)
[2] L. J. Giacoletto, *IRE Trans. ED, 207* (1957)
[3] F. M. Smits, *Proc. IRE 46*, 1049 (1958)
[4] A. Uhlir, Jr., *Proc. IRE 46*, 1099 (1958)

Solid State Physics At The National Bureau of Standards*

Solid state research at the National Bureau of Standards is part of a general scientific effort to solve the puzzles posed by different materials. During the past 10 years, since the invention of the transistor, the demands of technology for new electronic semiconducting devices have become more and more insistent. The Bureau helps meet this need by providing data on the basic properties of materials showing potentialities for practical application.

To help solve the problems posed by semiconducting materials and thus provide data needed for their effective application, the National Bureau of Standards conducts a program of solid state research sponsored in part by the Department of Defense.[1] Such a program forms a vital part of the overall scientific effort which has been brought to bear in the area of the solid state over the last few years. This branch of physics, seldom heard of as little as 15 years ago, is now one of the most active fields in present-day science. Since the invention of the transistor in 1948, demands have continued to increase not only for new semiconducting materials but for a better understanding of available materials which will allow a wider scope of application.

Although the technological application of semiconductors has played a great part in the rapid progress made in solid state research, the basic aims of the field are of a more fundamental nature. Primarily, solid state physics attempts to interpret the physical properties of matter in terms of the microscopic behavior of electrons, nuclei, and lattice vibrations. Advances toward this goal were first made during the thirties

*U.S. Department of Commerce, National Bureau of Standards, Washington, D.C. Summary Technical Report STR-2338, April 1959. SEMICONDUCTOR PRODUCTS wishes to express its appreciation to the National Bureau of Standards for permission to publish this report.

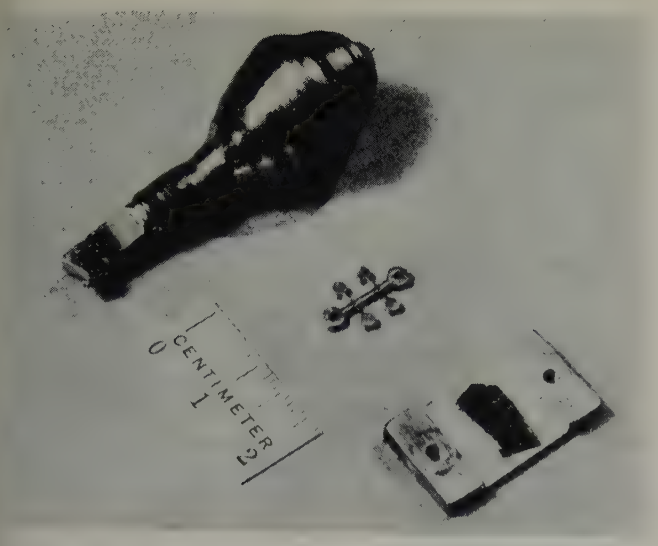

Fig. 1—Semiconductor intermetallic compounds studied in the National Bureau of Standards Solid-State Physics Section. Increased knowledge thus obtained on the behavior of semiconducting surfaces is of great importance for improving the operation of devices such as transistors and photodetectors. Left: Oriented crystal of indium-antimony (InSb). Center: Indium-antimony sample (cut with cavitron) prepared for elastoresistance measurements. Right: Cleaved and mounted specimen of magnesium-tin (Mg_2Sn) for optical investigations.

with the groundwork laid by Wilson and Sommerfeld for a quantum mechanical theory of electrons in crystals, and with the basis for understanding lattice properties provided by Born's work on crystal dynamics and Peierls' introduction of the phonon (quantized lattice vibration) concept. Toward 1940, solid state physics came into its own, probing the characteristics of matter in terms of these new theories.

The materials first investigated on the basis of electron and lattice theories were germanium and silicon —the elements employed in the transistor. As the scope of investigation broadened, silicon power rectifiers and voltage regulators, photodetectors for the infrared, and thermoelectric devices for power conversion or refrigeration were developed. Increased activity in solid state research at very low temperatures has more recently produced devices like the maser (a microwave amplifier) and the cryotron (a superconductive computer component). Studies of imperfections, such as vacancies, interstitials, and dislocations, have also pressed forward during the last ten years, and have recently made it possible to increase the strength of materials, especially metals. With the growing need for materials to withstand very high and very low temperatures, the results of such studies find immediate technological application.

The program of research presently under way at the Bureau deals with the electrical, thermal, optical, mechanical, and magnetic properties of certain materials. The behavior of these solids is studied by measuring either individual properties or combinations of properties such as thermoelectric power and electrostriction. The data thus obtained lead to a better understanding of the factors that cause solids to exhibit particular characteristics, and also yield much information about the structure of the solid state. Such studies allow the potentialities of a material for practical application to be evaluated.

The Bureau has been involved in the general effort to arrive at an understanding of semiconducting solids since 1949, when work on the properties of rutile (TiO_2 in one of its crystalline forms) was initiated. These studies led to a better understanding of the electronic behavior in rutile and eventually resulted in the development of a useful device, the titanium dioxide rectifier.

In 1952, attention was turned to a new class of materials, the III-V compounds—binaries formed between elements of the III-B and V-B columns of the periodic table. The Bureau was the first to undertake research on this group of new semiconductors. During the following two years many crystals of aluminum antimonide, gallium antimonide, and indium antimonide were prepared and their electrical and optical properties investigated. Later on, this research was extended to include studies of mechanical and magnetic behavior. InSb (indium antimonide) was shown to be an extremely interesting material for both basic research and for application to infrared photodetectors and galvanomagnetic devices. Consequently, appreciable effort is still devoted to InSb.

Other materials studied during the last five years are magnesium-tin and semiconducting gray tin. Recently attention has again been focused on TiO_2 as a result of heightened interest in thermoelectric devices, which has stimulated the study of oxide semiconductors, especially oxides of the transition metals.

Fig. 2—Some typical crystals studied at the National Bureau of Standards. Left: A crystal of bismuth telluride; right: Three crystals of InSb. In its program of solid state research, the Bureau studies the electrical, thermal, optical, mechanical, and magnetic properties of semi-conductors in crystalline form to provide data needed for successful technological application.

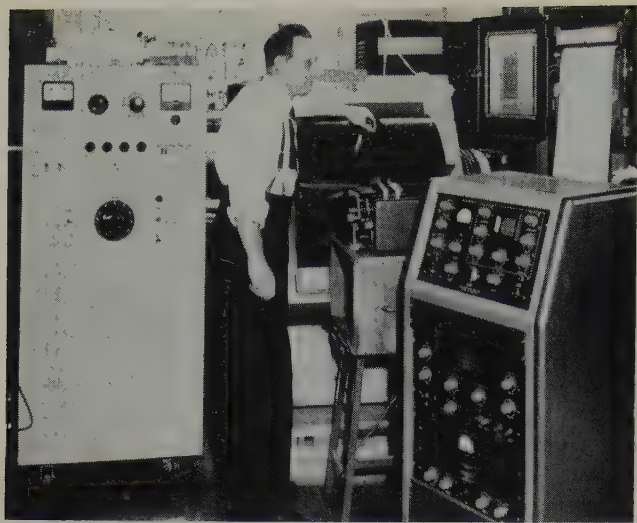

Fig. 3.—The National Bureau of Standards employs nuclear magnetic resonance as a tool for the investigation of the solid state. A study of the absorption of energy by atomic nuclei in solids leads to an understanding of the local electric and magnetic fields which the nuclei experience. Sample is contained in a probe between the pole pieces of the large magnet (regulated power supply for magnet at left). The probe is connected through an oscillator circuit (small box), power supply, lock-in detector, and modulator (all in console) to a strip chart recorder.

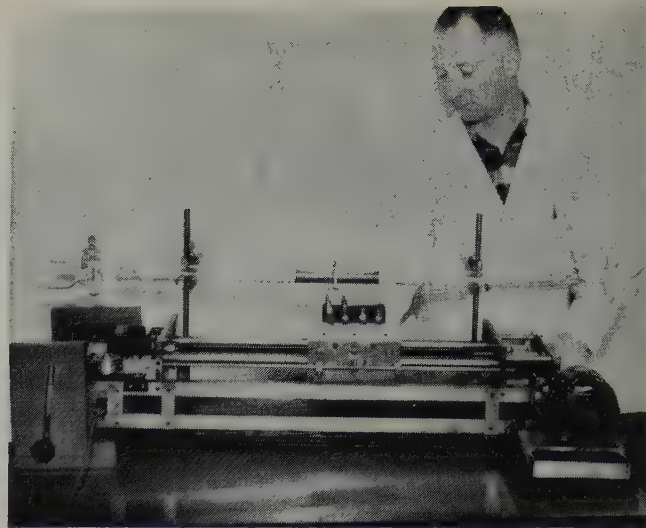

Fig. 4—Automatic zone melter recently constructed at the National Bureau of Standards. This device is used at the Bureau to obtain extremely high purity in semiconducting materials. Center: Water-cooled radio-frequency work coil used to melt the solid material to be purified. The coil surrounds a carbon boat which holds the bar of material. The driving motor and the return motor are on the right and left, respectively. The box in the foreground contains the motor controls.

Titanium dioxide was chosen as a prototype of this class and also as an example of a high-temperature semiconductor.

The program of research on the materials discussed can be broken down into the following projects: (1) Crystal growth and sample preparation; (2) measurement of electrical properties including conductivity, Hall effect, magnetoresistance, and thermoelectric power; (3) studies of optical absorption and photoconductivity; (4) determinations of the lifetime of optically excited charge carriers; (5) measurements of the mechanical and electromechanical properties, which include elastic constants, anelastic effects, piezoresistivity, and piezoelectric effects; (6) studies of nuclear magnetic resonance; and (7) further development of solid state theory.

Crystal Growth and Purification

As solid state materials are evaluated on the basis of electron and lattice theories, they must be studied in their crystalline form. Therefore, crystal growth and purification are a vital part of the Bureau's solid state research program. (Crystals of the III-V compounds are prepared by the Kyropoulos technique in which a seed crystal is immersed in a melt and then slowly removed. In this way, a large crystal is formed. During the last four years, over 100 crystals of InSb, mostly monocrystalline, have been grown by this technique.

To obtain information about the structure of the solid state, it is often necessary to have pure materials or materials with known contamination or doping. Therefore, before the final crystal growth, the crystal-forming substance is purified by the zone melting technique,[2] in which molten zones move through the substance leaving a purer material in their wake. Indium antimonide with purities as high as 10^{14} and 10^{15} impurities per cc (i.e. to 10 parts in 10^8) has been obtained with this method.

Electrical Property Measurements

The first measurements made on each new conducting crystal are of an electrical nature. Conductivity is of primary interest and is determined from the potential drop along a sample of rectangular shape. Additional information is then obtained by studying the Hall effect—the *emf* set up by the migration of charge carriers in a current-carrying conductor subjected to a magnetic field at right angles to the direction of the current flow. The sign of the Hall coefficient distinguishes between *n*- and *p*-type semiconductors; in the former, the current is carried by negative charges or electrons, while in the latter the conduction is due to positive carriers or holes (missing electrons). A third property investigated is the thermoelectric effect—the voltage between two ends of a specimen kept at different temperatures.

From the variation of these quantities with temperature, it is possible to obtain the information needed to understand the mechanism of conduction in the crystal and to evaluate the material for use in practical electronic devices. This information includes (1) intrinsic and extrinsic energy gaps, (2) number

of charge carriers, and (3) mobilities of electrons and holes. Measurements of the conductivity, Hall effect, and thermoelectric power are made down to liquid helium temperatures, as are most of the other property measurements on semi-conductors. Conductivity and thermoelectric power have been determined up to 1000°C.

Conductivity and Hall effect measurements on the III-V compounds have shown that this group of materials displays widely differing properties. Energy gaps range from 3.0 *ev* to 0.16 *ev*, and mobilities from 10^2 cm^2/volt-sec to 10^5 cm^2/volt-sec. As a material can usually be found which has properties tailored to a particular application, this class of compound is very important.

In the course of electrical property investigations at the Bureau, several phenomena of fundamental importance have been discovered. For example, during a measurement of the magnetoresistance of InSb as a function of magnetic field H at liquid helium temperature, it was observed that its behavior was not quadratic in H as expected from classical considerations, but showed instead several oscillations.[3] Subsequent investigations indicated that these oscillations were periodic in $1/H$. This phenomenon is closely associated with the oscillatory behavior of susceptibility, which has been observed in several metals and is known as the deHaas-Van Alphen effect. The effect occurs when the electron mean free path becomes a circular orbit. Under these circumstances, quantization of the electron orbits must be taken into account; the electronic energy states become discrete and produce oscillations in the diamagnetic and transport properties.

Optical Measurements

The present interest in employing semiconductors as infrared photodetectors requires a better understanding of the principles of the photoconductive process and information on new materials. To provide these data, which are essential for extending the application and reliability of detectors in the infrared, the Bureau measures absorption spectra and photoconductivity.[4] These investigations are carried out as a function of temperature, and interest is mainly focused on the infrared region. Some of the materials that have been studied are gallium antimonide, cadmium antimonide, indium antimonide and magnesium-tin; the intrinsic absorption edges of these substances lie in the 1 to 7μ wavelength range.

Recently an investigation of the photoconductive response of copper-doped InSb showed that fairly large photosignals can be obtained at liquid helium temperatures in the far infrared range up to 35μ. Interesting quenching effects were found in n-type InSb containing a slight amount of copper impurity.

Carrier Lifetime Studies

Carrier life-time τ—the length of time that an elec-

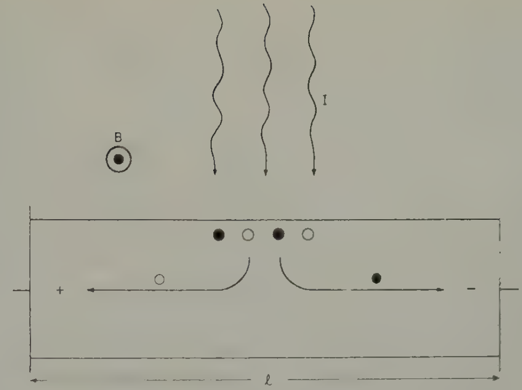

Fig. 5—Schematic diagram illustrating the photoelectromagnetic effect. The charge carriers are produced by the incident light I and deflected by the magnetic field B, perpendicular to the plane of the paper. The resulting current is in the direction of *l*. As the photoconductive signal and the current are directly related to the carrier lifetime, the National Bureau of Standards uses this effect to study the conduction process in certain semiconducting materials.

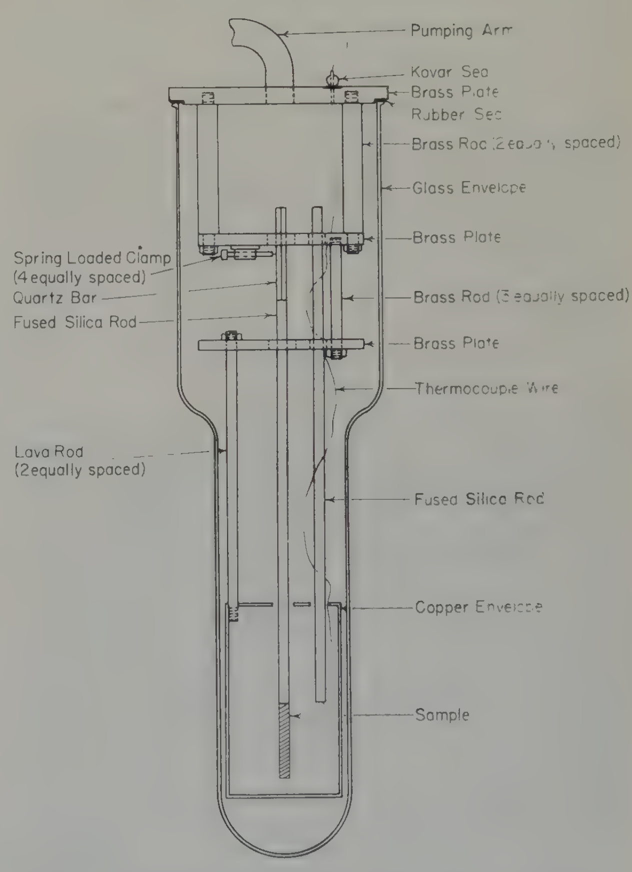

Fig. 6—Apparatus employed by the National Bureau of Standards in the composite oscillator technique of solid state research. The quartz crystal transducer which drives the sample is kept at room temperature; a fused quartz rod connects it with the specimen. Measurements of the relaxation peaks and attenuations can be related to dislocations, vacancies, interstitials, and chemical impurities in the sample. Investigations of this kind have been made on InSb up to its melting point (523 °C).

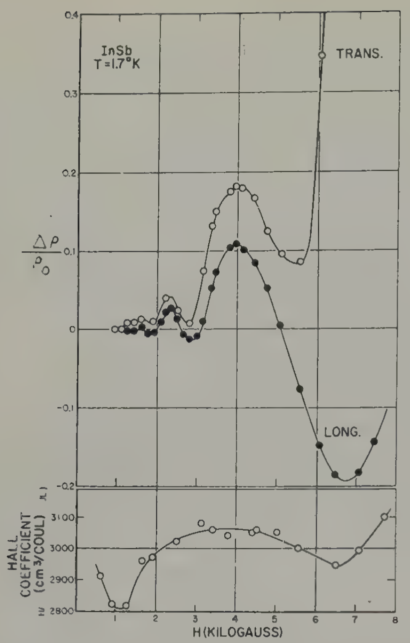

Fig. 7—The National Bureau of Standards has found that the resistance of n-type InSb as a function of magnetic field strength at liquid helium temperatures shows an oscillatory behavior. The magnetoresistance $\Delta\rho/\rho_0$ and the Hall coefficient determined for this material at 1.7°K are shown. The magnetoresistive effect, even at room temperature, is considerably larger than in other solids. This high magnetoresistance as well as the Hall effect can be utilized in constructing such devices as magnetometers, gyrators, and low-frequency amplifiers.

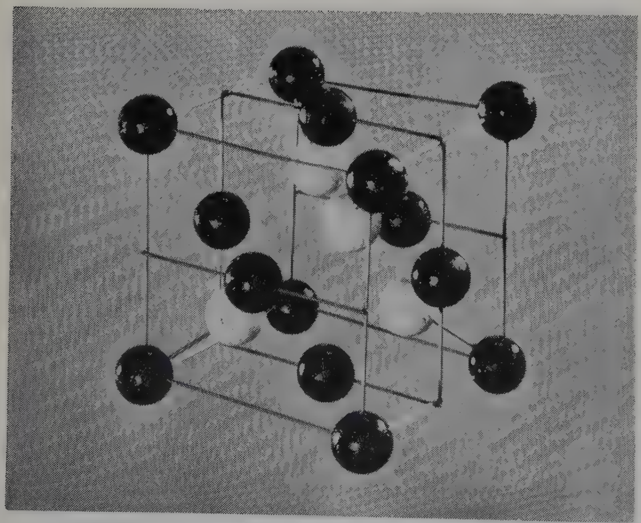

Fig. 8—The III-V binaries, semiconductors under study at the National Bureau of Standards, have a zinc blende crystal structure. This is a symmetrical structure in which atoms of both elements are located at the corners and at the centers of the faces of a cube. Two of these materials, InAs and InSb, show promise as infrared photodetectors.

tron (or hole) takes part in the conduction process before recombining with a hole (or electron) in the valence (or conduction) band—is one of the major parameters governing the conduction process in solids. Its numerical value is therefore of great importance in evaluating materials for application as rectifiers, transistors, and photodetectors. The Bureau carries out studies of carrier lifetime which, in addition to furnishing a critical value, provide a means of investigating the recombination and trapping processes in crystals.

Values of lifetimes are derived from measurements of the photoconductivity and the photoelectromagnetic effect. The photoelectromagnetic effect is a kind of Hall effect in which the charge carriers are produced by incident light and deflected in the sample by a magnetic field. The current is perpendicular to both the incident radiation and the field. It is proportional to $\sqrt{\tau}$, while the photoconductive signal is proportional to τ. Hence the value of the lifetime is obtained directly from the ratio of the two signals.

Mechanical and Electromechanical Studies

The Bureau investigates the basic nature of semiconductors by obtaining data on the mechanical properties of crystals. This information is also essential for the effective application of the semiconducting materials.

The mechanical behavior of semiconductors can be studied by means of several different experiments, some giving information about the state of the lattice and others about the electron assembly. An example of the former is a determination of the elastic constants.[5] These constants have been measured on single crystals of indium antimonide and the results were correlated with optical and thermal data. It appears that the values of the elastic constants are indicative of the partly ionic character of this compound.

Other experiments depend on the interaction of the lattice structure and the outer electrons. A recent measurement of the resistivity of n- and p-type InSb under the influence of tensile stress has confirmed the energy band structure of this material.

The study of internal friction is very well suited to investigations of imperfections. The temperature or frequency dependence of the mechanical damping often reveals relaxation peaks and attenuations, which can be related to dislocations, vacancies, interstitials, chemical impurities, and other irregularities. Some measurements of this kind have been made on InSb up to the melting point (523°C). The experimental method used was the composite oscillator technique in which the sample is driven by a quartz transducer. Similar measurements on TiO_2 have recently been started.

Nuclear Magnetic Resonance

Since its discovery 13 years ago, nuclear magnetic resonance has proved to be one of the most useful techniques for studying solids. The Bureau makes use

of this method to investigate defects and impurities in semiconducting materials. The solid being studied is contained in the coil of a resonant circuit between the poles of an electromagnet. As the circuit is tuned through its resonant frequency, the nuclei in the sample switch from one orientation to another with a net absorption of energy. The relaxation time—the time nuclei remain in the higher energy state—is measured by pulse equipment.

This series of investigations was initiated in 1956 with the determination of the temperature dependence of the spin-lattice relaxation time in sodium chloride. During the past year, emphasis has been placed on the spin-lattice interaction in aluminum antimonide as deduced from the resonance of the aluminum nuclear spin.

Development of Theory

The experimental work carried out at the Bureau has been designed to cover a wide area of physical measurements. In this way investigations form a network of closely connected approaches to the understanding of the electronic and lattice structure of particular solids. To this end, the data provided for the development of new devices and improved engineering materials are complemented by the formulation of theories. For example, experimental studies have resulted in a theory for transport phenomena in a strong magnetic field, and in a better understanding of the electronic energy-band scheme of TiO_2 containing vacancies or impurities.

Future research in solid state physics at the Bureau will continue to concentrate on a few materials in working toward more complete data and adequate theories to describe observed phenomena. For example, during the coming year TiO_2 will receive particular emphasis; electrical, optical, and magnetic investigations of this material will provide valuable information concerning the role of impurities in the conduction mechanism. By studying a single material from several different angles in this way, the Bureau will continue to fulfill its basic function of supplying materials data while also providing a basis for the development of new devices and better engineering materials.

References

[1] For a description of early research at NBS, see Solid State Electronics, *NBS Tech. News Bul. 35*, 22 (February 1951).

[2] Zone Melting Apparatus, *NBS Tech. News Bul. 39*, 81 (June 1955).

[3] Galvanomagnetic Effects in n-type Indium Antimonide, by H. P. R. Frederikse and W. R. Hosler, *Phys. Rev.* 108, 1136 (1957).

[4] Photoeffects in Intermetallic Compounds, by H. P. R. Frederikse and R. F. Blunt, *Proc. IRE* 43, 1828 (1955).

[5] Elastic Moduli of Indium Antimonide, by R. F. Potter, *Phys. Rev.* 103, 47 (1956).

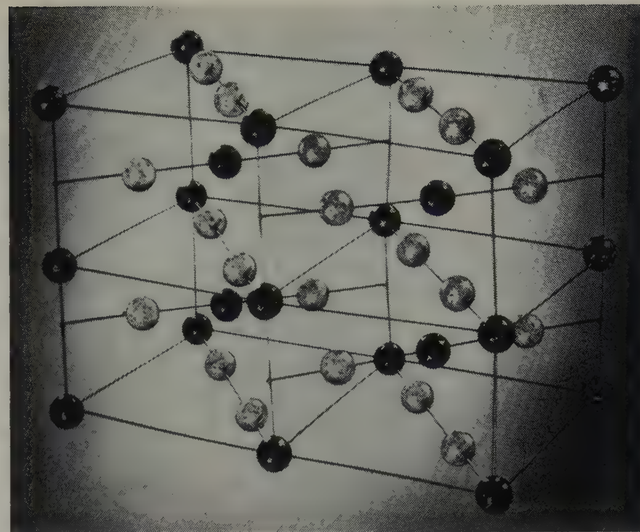

Fig. 9—Model of titanium dioxide in the crystalline form of rutile—a material currently under study at NBS. This material can be made semiconducting by the addition of foreign ions or loss of oxygen (represented by the light balls). It is representative of a class of oxide semiconductors, which exhibit properties showing promise for thermoelectric devices.

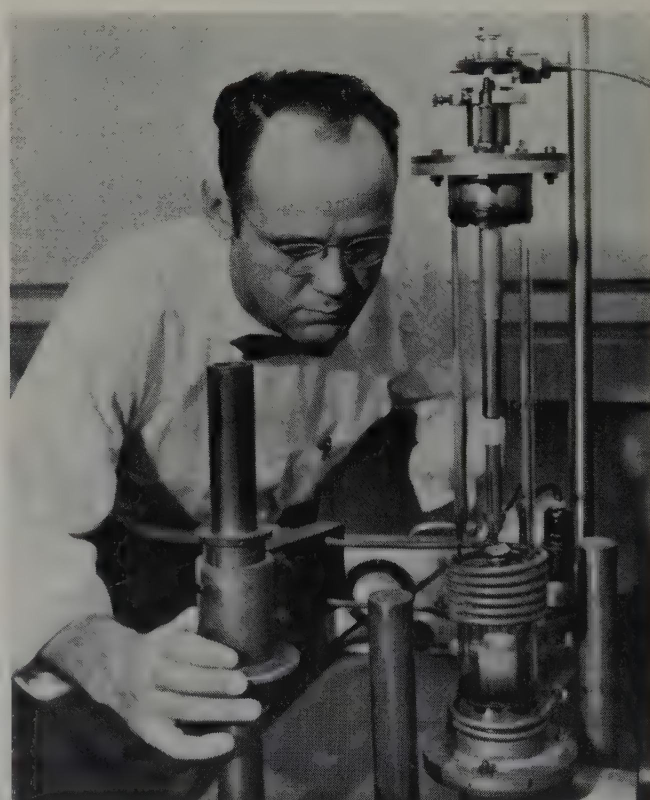

Fig. 10—Furnace used at the National Bureau of Standards to grow crystals by the Kyropolos technique. The coil surrounding the vacuum chamber provides a temperature sufficient to keep the metal in the small cup molten. As a seed crystal is removed very slowly from the melt, the metal adhering to it reaches the melting point and starts to solidify, forming a large single crystal.

APPLICATIONS ENGINEERING DIGESTS

APPLICATIONS ENGINEERING DIGEST NO. 21

Transistor Dissipation Ratings for Pulse and Switching Service; Radio Corporation of America, Somerville, N.J.

The permissible dissipation of a transistor is determined by the maximum permissible temperature of its collector junction (usually given in published data as "Maximum Storage Temperature"). Published maximum-dissipation ratings for RCA transistors are for class A or class B operation with signals having sinusoidal waveforms. These ratings do not apply for pulse or switching service.

When a transistor is used in pulse or switching service its instantaneous dissipation may greatly exceed its class A or class B dissipation rating, depending upon the pulse width and pulse-repetition rate employed. The resulting rise in collector-junction temperature depends upon the thermal time constant and thermal resistance of the transistor, and may easily be great enough to destroy the transistor unless the peak dissipation is limited to a safe value. Because it is impractical to give maximum-peak dissipation values for all possible combinations of pulse width and duty cycle in the published data for a transistor, the value for a specific pulse or switching application must be determined by the circuit designer.

Determination of Permissible Dissipation

To help circuit designers determine these peak-dissipation values, this Note gives the maximum permissible collector-junction temperatures, typical thermal resistances of 39 RCA transistor types specially designed for or frequently used in pulse and switching service.

When a power pulse is applied to a transistor the resulting change in the temperature of the collector junction is determined by the pulse amplitude and width, and by the thermal time constant and thermal resistance of the transistor. The junction temperature is a maximum at the termination of the pulse and reaches its minimum value during the interval after the pulse has been removed. The junction temperature at any instant during the applied pulse is given by Eq. 1.

The temperature to which the junction cools after the pulse has been removed is given by Eq. 2. ΔT_j (max) is the difference between the maximum temperature reached by the junction during the pulse and the ambient temperature $[T_{j1}(t) - T_a]$

With repeated pulses the maximum temperature of the collector junction approaches the limit given by Eq. (3).

The maximum rise in junction temperature in normalized form is given by Eq. (4).

Circle 198 on Reader Service Card

$$T_{j1}(t) = PR_T\left(1 - \frac{8}{\pi^2}\sum_{n=1,3,5\ldots}^{\infty}\frac{1}{n^2}\epsilon^{-\frac{t}{\frac{1}{n^2}\tau_1}}\right) + T_a \quad (1)$$

where t is the time after application of the pulse in seconds

P is the amplitude of the power step in watts

R_T is the thermal resistance of the transistor in degrees C per watt

τ_1 is the thermal time constant of the transistor in seconds

T_a is the ambient temperature in degrees C.

$$T_{j2}(t) = \left(\Delta T_j(\max)\frac{8}{\pi^2}\sum_{n=1,3,5\ldots}^{\infty}\frac{1}{n^2}\epsilon^{-\frac{t}{\frac{1}{n^2}\tau_1}}\right) + T_a \quad (2)$$

where t is the time after removal of the pulse in seconds

$$T_j = PR_T\left(\frac{1-a}{1-ab}\right) + T_a \quad (3)$$

where

$$a = \left(\frac{8}{\pi^2}\sum_{n=1,3,5\ldots}^{\infty}\frac{1}{n^2}\epsilon^{-\frac{t_0}{\frac{1}{n^2}\tau_1}}\right)$$

$$b = \left(\frac{8}{\pi^2}\sum_{n=1,3,5\ldots}^{\infty}\frac{1}{n^2}\epsilon^{-\frac{t_0}{\frac{1}{n^2}\tau_1}\left(\frac{1-d}{d}\right)}\right)$$

t_0 is the pulse width in seconds

d is the duty cycle $\left(\frac{t_0}{\text{pulse repetition period}}\right)$

$$\frac{\Delta T_j(\max)}{P(\max)R_T} = \frac{1-a}{1-ab}$$

$$= \frac{\left(1 - \frac{8}{\pi^2}\sum_{n=1,3,5\ldots}^{\infty}\frac{1}{n^2}\epsilon^{-\frac{t_0}{\frac{1}{n^2}\tau_1}}\right)}{1 - \left(\frac{8}{\pi^2}\sum_{n=1,3,5\ldots}^{\infty}\frac{1}{n^2}\epsilon^{-\frac{t_0}{\frac{1}{n^2}\tau_1}}\right)\left(\frac{8}{\pi^2}\sum_{n=1,3,5\ldots}^{\infty}\frac{1}{n^2}\epsilon^{-\frac{t_0}{\frac{1}{n^2}\tau_1}\left(\frac{1-d}{d}\right)}\right)} \quad (4)$$

where τ_1 and R_T are, respectively, the thermal time constant of the transistor and the thermal resistance between the collector junction and the transistor case.

APPLICATIONS ENGINEERING DIGEST NO. 22

An Introduction To Parametric Amplifiers; J. Ekiss, Lansdale Tube Co., Lansdale, Pa.

Recent theoretical and experimental investigations have led to the development of a new class of amplifiers for use in the *uhf* and microwave region. Various names of which parametric amplifier, reactance amplifier, varactor, and MAVAR (for mixer amplification by variable reactance or modulator amplifiers using variable reactance) are representative, have been used in the literature to describe these amplifiers. Apparently the term parametric amplifier has gained much popularity so that that name will be used here.

This report, the first in a series, is a result of a literature survey which is being carried out to learn more about the field of parametric amplifiers. This note, introductory in nature, will serve to provide:

(1) a short history of the development of parametric amplifiers,
(2) the fundamental principles upon which parametric amplification is based,
(3) a description of the various types of parametric amplifiers,
(4) the results of recent experimental work as described in the literature as regards diode-type amplifiers, and
(5) a fairly detailed bibliography of books, articles, and papers pertaining to parametric amplifiers.

Types of Parametric Amplifiers.

Parametric Amplifiers may be classified according to whether the nonlinear reactance is a "lumped parameter" or a "distributed parameter." This classification may be further broken down by typifying the manner in which the nonlinear reactance is obtained.

A. Lumped Parameter Amplifiers

1. Ferrite version:

In this type of amplifier a ferromagnetic material is used to provide a nonlinear inductance; i.e., an inductance in which the flux linkage is a nonlinear function of the current is used as the reactive element.

2. Diode version:

In this amplifier the nonlinear capactance of a reverse-biased, semiconductor diode is used as the reactive element.

B. Distributed Parameter Amplifiers

1. Traveling-wave ferrimagnetic amplifier.

A recent theoretical investigation by Tien and Suhl has led to the proposal for a new type of parametric amplifier. In one form the amplifier consists of two transmission lines embedded in a ferrite material. The coupling between the two lines is varied (with time and distance along the line) by the local oscillator. The distributed coupling may be thought of as a coupling between nonlinear inductors.

2. Electron Beam Versions

At present there appear to be two forms of electron beam parametric amplifiers.

a. An electron beam may be used to produce an effective admittance in a microwave cavity. By proper adjustment of the cavity, a pure susceptance may be produced. If the electron beam is then modulated by a local oscillator, the susceptance will vary at a rate determined by the local oscillator frequency. If the local oscillator frequency is equal to twice the signal frequency, a negative conductance will be introduced into the signal cavity. Amplification of the signal may then take place.

b. The other type of electron beam parametric amplifier makes use of the long-known fact that space-charge waves may be propagated (with no attenuation) along an electron beam. Let a d-c electron beam be modulated by a signal of frequency ω_s. Then one may show that two space charge waves will propagate along the beam. One wave will be a "fast wave" and the other a "slow wave." If the electron beam is simultaneously modulated by a pump of frequency $2\omega_s$, then the fast wave (which varies at the *signal* frequency) may be made to *increase* exponentially with distance along the beam. By coupling to this fast wave at a suitable point along the beam, the amplified signal may be extracted. One feature of this type of amplifier is that the noise content of the input signal may (by proper loading of the input cavity) be eliminated. Hence, very low noise figures (in the order of 1 *db*) may be expected.

Bibliography

1. "Three-Frequency Theory of Amplification in Nonlinear-Reactance Modulators" by M. E. Hines, presented at the 16th Annual Conference of Electron Tube Research, Berkeley, Calif., June, 1957.

2. "Energy Relations of Nonlinear Elements," J. M. Manley and H. E. Rowe, Proceedings of the I.R.E., July, 1958.

3. "Oscillations in System with Nonlinear Reactance," R. V. L. Hartley, *Bell System Technical Journal*, Vol. 15, July, 1936.

4. "Noise Figure Measurements on Two Types of Variable Reactance Amplifiers Using Semiconductor Diodes" A. Uhlir, Jr., et al, *Proceedings of the I.R.E.*, June, 1958.

5. *Crystal Rectifiers*, H. C. Torrey and C. A. Whitmer, MIT Radiation Lab Series, McGraw-Hill Book Co., Inc., New York, N.Y. Vol. 15, Chapt. 13; 1948.

6. "Some General Properties of Nonlinear Elements. II. Small Signal Theory" H. E. Rowe, *Proceedings of the I.R.E.*, May, 1958.

7. "Theory of Parametric Amplification Using Nonlinear Reactances," S. Bloom and K. K. N. Chang, *RCA Review*, December, 1957.

8. "Parametric Amplifier Using Lower-Frequency Pumping," S. Bloom and K. K. N. Chang, *Proceedings of the I.R.E.*, July, 1958.

9. "Gain and Noise Figure of a Variable — Capacitance Up-Converter," D. Leenov, *Bell System Technical Journal*, July, 1958.

10. "A Traveling Wave Ferrimagnetic Amplifier," P. K. Tien and H. Suhl, *Proceedings of the I.R.E.*, April, 1958.

11. "Experimental Characteristics of a Microwave Parametric Amplifier Using a Semiconductor Diode," H. Heffner and K. Kotzbue, *Proceedings of the I.R.E.*, June, 1958.

12. "A Low-Noise Wide-Band Reactance Amplifier," B. Salzberg and E. W. Sard, *Proceedings of the I.R.E.*, June 1958.

13. "The Mavar: A Low-Noise Microwave Amplifier," S. Weber, *Electronics*, September, 1958.

14. "Proposal for a Ferromagnetic Amplifier in the Microwave Range," H. Suhl, *Physical Review*, April, 1957.

15. "Solid-State Microwave Amplifier and Oscillator Using Ferrites," M. T. Weiss, *Physical Review*, July, 1957.

16. "A Parametric Electron Beam Amplifier," T. J. Bridges, *Proceedings of the I.R.E.*, pp 494-495, February, 1958.

17. Noise, A. Van der Ziel, Chapt. 15, Prentice-Hall, Inc., New York, N.Y., 1954.

APPLICATIONS ENGINEERING DIGEST NO. 23

A Survey of Some Circuit Applications of the Silicon Controlled Switch and the Silicon Controlled Rectifier; Solid State Products Inc., Salem, Mass.

The PNPN silicon controlled switch is an active switching element with characteristics similar to those of a gas thyratron. That is, it will remain in a non-conducting or "off" state until turned on or "fired" by a low level control signal. It will then remain on without the need for sustaining control signal. The controlled switch is turned off by reducing its anode current to

[*Continued on page 64*]

SEMICONDUCTOR & SOLID-STATE BIBLIOGRAPHY

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
The Theory of the Indirectly Heated Thermistors Part 4	Acta Poly Scandinav El 5 (255/1959)	Thermistor theory is extended to indirectly heated thermistor in order to make possible the handling of pertinent circuit problems.	N. Bjork
A Portable Frequency Standard	Bell Labs Record May 1959	A transistorized crystal controlled oscillator capable of operating between 5 to 50 *mc* is described.	L. F. Koerner
Hall Effect Devices	Bell Syst Tech J1 May 1959	Survey paper includes original work done in this field. Most desirable semiconductor materials for these devices are discussed.	W. J. Grubbs
Analysis and Design of a Transistor Blocking Oscillator Including Inherent Nonlinearities	Bell Syst Tech J1 May 1959	Analysis differs from previous approaches in that the nonlinear dependence of collector current and base voltage upon base current is considered.	J. A. Narud M. R. Aaron
Stabilization of Silicon Surfaces by Thermally Grown Oxides	Bell Syst Tech J1 May 1959	A study has been carried out of the stability of silicon surfaces when they are provided with a chemically bound solid-solid interface.	M. M. Atalla E. Tannenbaum E. J. Schreibner
Analysis of Phonon-Drag Thermomagnetic Effects in *n*-Type Germanium	Bell Syst Tech J1 May 1959	Study has been made of the Nernst effect and the variation of thermoelectric power with magnetic field for single crystal samples of *n*-type Ge.	C. Herring T. H. Geballe J. E. Kunzler
A Silicon-Controlled Rectifier	Communications and Electronics May 1959	Discussion of construction, electrical characteristics, and ratings.	D. K. Bisson R. F. Dyer
Phase-Controlling Kilowatts with Silicon Semiconductors	Control Engineering May 1959	Author discusses basic unijunction controlled rectifier circuitry, and introduces specific circuits for motor control, illumination, heat, and clutch systems control.	F. W. Gutzweller
Transistorized Programmer Runs 35,000-Ton Press	Control Engineering May 1959	Description of a transistorized digitally-programmed speed-control system in a very large press.	L. Robbins A. L. Licardi
Transistors Demonstrate Reliability in Critical Nuclear Instrumentation	Electrical Mfg May 1959	Included in this discussion are differential amplifiers, chopper-modulator amplifiers, diode-ring modulators and conventional direct-coupled amplifiers.	R. F. Shea
Worst Case Design Equations for Transistor Logic Circuits	Electronic Design May 1959	A rigorous approach to provide for unusual circumstances is developed and presented to permit a wider range of application.	C. W. Campbell Jr
Evaluating Infrared Photon Detectors	Electronic Design May 1959	Article reviews responsitivity, noise equivalent power, detector noise considerations, and suggests some approaches when data is lacking.	F. Rosell
Avalanche Transistors	Electronic Eng (Br) May 1959	Investigations are made of the properties of some experimental alloyed junction avalanche transistors. Design data are given and applications summarized.	R. C. V. Macario
Transistors and Cores in Counting Circuits	Electronic Eng (Br) May 1959	It is shown how the two devices can be combined to form non-critical reliable counting circuits capable of handling input frequencies up to 75 *kc*.	F. Rozner P. Pengelly
The Charge Storage in a Junction Transistor during Turn-off in the Active Region	Electronic Eng (Br) May 1959	Equations are derived for the emitter and collector currents that exist under conditions of minimum turn-off time.	R. S. C. Cobbold
Accurate Measurement of Transistor Cut-Off Frequency	Electronic Eng (Br) May 1959	An equipment is described for the quick and accurate measurement of current gain of high frequency transistors between 1 to 20 *mc*.	Y. Tarui
The Transfer Element	Electronic Equip Eng May 1959	Development of a two-terminal symbol for transfer elements having special coupling effects.	R. B. Hurley
How to Design for Transistor Reliability—III	Electronic Equip Eng May 1959	Discussion of properties of semiconductor devices that limit their applications in practical circuits.	J. B. Hangstefer L. H. Dixon Jr.
Infrared Radiation—Materials	Electronic Equip Eng May 1959	Discussion of photo-conductive detectors and presentation of the characteristics of various optical materials useful for components such as prisms, windows and domes.	C. R. Betz
How to Measure Transistor Input and Output Impedances	Electronic Equip Eng May 1959	Procedure described covers 455 *kc i-f*, and is applicable for measurements at other frequencies.	D. Russell Jr.
Designing Transistorized Video Amplifiers, Part 1	Electronic Industries May 1959	Author employs step-by-step method of design, posing problem first and then effecting solution. Two types of 3-transistor circuits are described.	R. G. Salaman
Using Unusual Semiconductors	Electronic Industries May 1959	Possible advantages of going to unusual materials, especially compounds, are presented and studied.	H. L. Armstrong
Transistorizing a Flip-Flop	Electronic Industries May 1959	An example illustrates the design methods used.	A. I. Perlin
Transistors Simplify Control of Target Drone	Electronics May 1 1959	Pulse symmetry and repetition rate control servos which drive rudder and elevator. Pulses modulate the transmitted carrier picked up by superregenerative receiver on plane.	G. B. Herzog
Transistor Dual Conversion for Marker-Beacon Receivers	Electronics May 8 1959	With same sized transistorized adapter, one-indicator-light receiver is converted to three-indicator-light receiver weighing about two pounds.	R. G. Erdmann
How to Design Reflexed Transistor Receivers	Electronics May 8 1959	Reflex circuits in which *i-f* and *a-f* gain are achieved in the same transistor stage are discussed. Careful design is required to avoid motorboating.	John Waring
Theory and Use of Field Effect Tetrodes	Electronics May 8 1959	Basic concepts of the unit are presented together with specific applications as a transformer, as a gyrator, as a modulator, and as a negative-resistance device.	H. A. Stone, Jr.
Transistor Circuits for Power-Line Carrier	Electronics May 15, 1959	Carrier-current transmitter and receiver uses 200-*cps* channel bandwidth and 500-*cps* channel spacing to fit more channels into power-line carrier spectrum.	K. Stenerson
Servo Preamplifiers Using Direct-Coupled Transistors	Electronics May 15, 1959	Direct-coupled amplifier uses Zener diode to provide constant emitter voltage to one of the transistors. Amplifier is stable for transistors having a beta range of nearly 3 to 1.	A. N. Desautels
Transistor Amplifiers for Reactor Control	Electronics May 22 1959	Logarithmic and period amplifiers used in nuclear reactor startup ranges are transistorized with the exception of log diodes and electrometers.	E. J. Wade D. S. Davidson

TITLE	SOURCE	ABSTRACT	AUTHORS
Design of Transistor Vertical Deflection Output and Driver Stages	IRE Trans B&TV Rec May 1959	Power is a prime consideration in battery-operated portable TV receivers. For this reason *a-c* coupling with its lower power requirements is considered an important objective.	M. J. Hellstrom
Transistor Television Picture I.F. Double Tuned Amplifiers	IRE Trans B&TV Rec May 1959	A 3-transistor amplifier is described. Choice of transistors, design of output stage, AGC and traps are discussed.	H. C. Lee
Frequency Characteristics of a Semiconductor Rectifier at Voltages Greater Than RT/q	IRE Trans Elec Devcs April 1959	It is found that in higher voltages the half-power f is very dependent on voltage as well as load resistance, carrier lifetime and reverse saturation current.	W. E. Newell L. Depian A. G. Milnes
A Lumped Model Analysis of Noise in Semiconductor Devices	IRE Trans Elec Devcs April 1959	It is found that all the noise may be accounted for by associating a noise-current generator with each of the conductances appearing in the lumped model.	R. N. Beatie
A Physical Theory of Junction Transistors in the Collector-Voltage Saturation Region	IRE Trans Elec Devcs April 1959	Numerical calculations have been carried out for the saturation voltage, base input voltage, and *d-c* current amplification factor for different geometrics and material properties.	C. Huang
Surface and Geometry Effects on Large Signal Base Input Voltage and Input Resistance of Junction Transistors	IRE Trans Elec Devcs April 1959	A design theory is presented with emphasis on the effect of surface recombination and transistor geometry.	C. Huang C. M. Chang M. Weissenstern
On the Theory of DC Amplification Factor of Junction Transistors	IRE Trans Elec Devcs April 1959	The diffusion equation is solved, and an analytic expression for the *d-c* amplification factor is presented in terms of arbitrary bulk lifetime and surface-recombination velocity and the geometry of the transistor.	S. Wang T. T. Wu
An Alloy-Diffuse Silicon High Current Transistor with Fast-Switching Possibilities	IRE Trans Elec Devcs April 1959	A method is described for fabricating a high-power silicon transistor capable of operating at case temperatures exceeding 100°C.	D. Navon P. Debeurs
High-Level Transistor Operation on Transport Capacitance	IRE Trans Elec Devcs April 1959	A two dimensional analysis of high-level transistor operation is presented which includes extended base region and other pertinent effects.	K. E. Mortenson
Bibliography on Electroluminescence and Related Topics	IRE Trans Elec Devcs April 1959	References have been classified as: General. Effects of Electric Fields in Solids. E-L in Zinc Sulfide. E-L in other materials. Field effects in Excited Phosphors. Galvanoluminescence.	H. F. Ivey
The Variable-Capacitance Parametric Amplifier	IRE Trans Elec Devcs April 1959	Physical principles review and a qualitative explanation is given of the variable capacitance effect in semiconductor diodes.	E. D Reed
Some Surface Properties of Silicon-Carbide Crystals	J1 Applied Physics May 1959	The work functions of a number of commercial grade silicon-carbide crystals have been obtained in high vacuum.	J. A. Dillon Jr. R. E. Schlier H. E. Farnsworth
Form Effect in Linear Magnetostriction	J1 Applied Physics May 1959	Use is made of the principle of virtual work to make a calculation of the form effect as dependent upon the intensity of magnetization.	H. E. Stauss
On the Theory of the Peltier Heat Pump	J1 Applied Physics May 1959	The figure of merit for a single stage Peltier heat pump is optimized in the region of partial Fermi degeneracy.	E. S. Rittner
On the Mechanism for Carrier Excitation in CdS	J1 Applied Physics May 1959	Induced conductivity in CdS crystals produced by electron bombardment (cathodoconductivity) and the associated x-ray production have been studied.	D. D. Snyder C. E. Bleil
Space Charge in Semiconductors Resulting from Low Level Injection	J1 Applied Physics May 1959	A solution of the continuity equations is obtained for the space charge distribution by making certain assumptions.	M. Green
Effect of Heat Treatment upon the Electrical Properties of Indium Arsenide	J1 Applied Physics May 1959	Large reversible variations in carrier concentration, Hall mobility, and carrier lifetime have been produced in InAs by heat treatment.	J. R. Dixon D. P. Enright
Indium Antimonide Photo-electromagnetic Infrared Detector	J1 Applied Physics May 1959	The theory of operation, construction, and performance data of an infrared detector based on the PEM effect in InSb are presented.	P. W. Kruse
The Luminescent Center in Self-Activated ZnS Phosphors	J1 Electrochem Soc May 1959	It is shown that a Zn vacancy is involved, and that the spectrum depends on the occupancy by a coactivator at the Zn or S site near the vacancy.	J. S. Prener D. J. Weil
A Double Diffused Silicon High-Frequency Switching Transistor Produced by Oxide Masking Techniques	J1 Electrochem Soc May 1959	A process for producing the localized emitter structure is described employing the masking property of SiO_2 against the subsequent phosphorus diffusion.	J. F. Aschner C. A. Bittman W. F. J. Hare J. J. Kleimack
Surface Potential, Field-Effect Mobility, and Surface Conductivity of ZnO Crystals	Physical Review May 1 1959	Measurements of surface properties of ZnO crystals were made at 300°K both in dry O_2 and in high vacuum.	H. J. Krusemeyer
Transport Properties of Nondegenerate n-Type Semiconductors Considering Electron-Electron Scattering	Physical Review May 1 1959	In this paper the authors propose two analytical functions which make the integrals appearing in transport theory readily integrable.	M. S. Sodha Y. P. Varshni
Hot Electron Behavior in Germanium under the Influence of a Magnetic Field	Physical Review May 1 1959	The theory of the hot-electron problem in many-valley semiconductors based upon the individual ellipsoidal energy surface model is extended.	L. Gold
Optical Properties of Tellerium and Selenium	Physical Review May 1959	Investigations were made at wavelengths extending from the intrinsic absorption edge to about 152 microns using polarized radiation.	R. S. Caldwell H. Y. Fan
Thermoluminescence and F-Centers. I. Theory II. Experimental.	Physical Review May 15 1959	Consideration in detail of the thermoluminescence arising from thermal bleaching of F-centers in irradiated alkali halides.	G. Bonfiglioli P. Brovetto C. Cortese
Hall Effect Resistivity, and Magneto-Resistivity of Th, U, Zr, Ti, and Nb	Physical Review May 15 1959	Characteristics have been studied at temperatures between ∼1°K and room temperature and in magnetic fields up to 30 kilogauss.	T. G. Berlincourt
Lifetimes and Capture Cross Sections in Gold-Doped Silicon	Physical Review May 15 1959	Determined by applying an electric field and measuring the amplitude of the pulses produced by α-particles.	W. D. Davis
The DOFL Microelectronics Program	Proceedings IRE May 1959	Fourteen-component-part transistorized binary counters were fabricated on ½ inch squares of steatite ceramic, 1/50 inch in thickness. Useful techniques are discussed.	T. A. Prugh J. R. Nall N. J. Doctor
Naval Ordnance and Electronics Research	Proceedings IRE May 1959	Two programs of electronics research are reviewed. These are photoconductor research and polarity coincidence correlation.	W. W. Scanlon G. Lieberman

TITLE	SOURCE	ABSTRACT	AUTHORS
A Lightweight and Self-Contained Airborne Navigational System	Proceedings IRE May 1959	Design of a self-contained navigational aid for aircraft. In Part III-Circuit Implementation of the Radar a description of the transistorized circuitry is given. This includes the modulator, I.F. amplifier, 3 *mc* detector, Janus multiplier, frequency tracker, power supplies, and regulators.	R. K. Brown N. F. Moody P. M. Thompson R. J. Bibby C. A. Franklin J. H. Ganton J. Mitchell
Anomalous Behavior in the Hall Coefficients of the Semiconducting Compounds SnSe and GeSe	Proc Phys Soc (Brit) May 1959	ρ and R does not vary in accordance with anticipated curves during certain temperature variations. An explanation is advanced.	S. Asanabe A. Okazaki
Lattice Screening in Polar Semiconductors	Proc Phys Soc (Brit) June 1959	The influence of space charge screening on election-phonon scattering in a polar semiconductor is discussed.	S. Domach
The Grain-Boundary Amplifier	Proc Phys Soc (Brit) June 1959	The grain boundary sheet conductance of an *n*-type crystal can be modulated by an applied electric field, thereby leading to a grain-boundary amplifier.	O. A. Weinreich H. Matare B. Reed
The Floating Zone Process	Res Appd in Ind (Br) May 1959	Article describes the process by which material can be zone refined and grown into single crystals without a crucible container.	W. Bardsley
Avalanche Noise in P-N Junctions	Semiconductor Prod May 1959	A unique type of noise when a p-n junction diode is operated at the onset of the avalanche region is studied.	S. Sherr S. King
An Analysis of Impurity Distributions and their Relation to Electrical Behavior of Conventional Transistor Constructions, Part 2	Semiconductor Prod May 1959	Four types of distributions were considered in the first article. In this installment the remaining six are discussed. Performance qualities of each type are summarized in tabular form.	P. Kaufmann G. Freedman
Performance of Transistors as Tuned Power Amplifiers at VHF	Semiconductor Prod May 1959	Results are presented of an investigation to determine the power capability of transistors operating at 70-100 *mc*.	B. Reich W. Orloff
A New Technique for Measuring Transistor Switching Times	Semiconductor Prod May 1959	The measurement of transistor switching times is described, and problems in present methods are discussed. The new method is explained.	R. R. Johnson R. D. Lohman R. R. Painter
Many-Electron Examination of the Hole Zone in Diamond-Type Crystals	Sov Phys Sol State Vol 1 No 2 2/59	The parameters are developed on the basis of a comparison of the results obtained with experimental data.	E. I. Kaplunova
On the Spin Mechanism of Recombination of Current Carriers in Ferromagnetic Semiconductors	Sov Phys Sol State Vol 1 No 2 2/59	The process of recombination of current carriers with transfer of the liberated energy to spin waves is discussed; order of magnitude of the capture cross section is estimated.	V. L. Bonch-Bruevich
On the Impurity Conduction in Liquid and Amorphous Semiconductors	Sov Phys Sol State Vol 1 No 2 2/59	Results suggest that in amorphous semiconductors the mechanism of impurity conduction does not work. This paper suggests ideas which will help to understand this property.	I. Z. Fisher
The Relationship between Electrical Conductivity and Electron Density Distribution in Germanium Crystals	Sov Phys Sol State Vol 1 No 2 2/59	A comparison was made of the x-ray reflection intensities of germanium crystal of different conductivity at various temperatures, and the results interpreted.	Yu. N. Shuvalov
The Application of the Photomagnetoelectric Effect to the Measurement of Surface Recombination Velocity	Sov Phys Sol State Vol 1 No 2 2/59	The method consists of compensating the PME voltage by the photo-conductivity voltage.	T. I. Galkinu
Electrical Properties and Structure of Compound Oxide Semiconductors. 1. MnO- CuO CoO- O_2 System	Sov Phys Sol State Vol 1 No 2 2/59	The importance of manganese cations in the conductivity of these materials is explained on the basis of new conductivity mechanism concepts.	I. T. Sheftel' A. I. Zaslavskii E. V. Kurlina G. N. Tekster-Proskuryakova
Zone Melting of Silicon with an Electron Beam	Sov Phys Sol State Vol 1 No 2 2/59	Description of an apparatus capable of creating a molten zone in silicon by direct election bombardment of the material to be purified.	V. Gusa I. Krzhizh I. Ladnar
Crucible-Less Evaporation of Silicon	Sov Phys Sol State Vol 1 No 2 2/59	Electron bombardment is used. A diagram and an external view of the apparatus is shown, and a description is given.	R. M. Voitenko T. N. Dvnaeva E. A. Kolenko
The Electric Double Layer and the Adhesion of Solids	Sov Phys Sol State Vol 1 No 2 2/59	The general case of a contact between a semiconductor and a metal are considered. Results may be of interest in connection with the manufacture of photoelectric cells and junction transistors.	V. B. Sandomerski V. P. Snulga
Silicon Transistors	U S Govt Res Reports May 15 1959	Objectives attained have made possible the solving of many of the technical problems involved in the manufacture of silicon devices. Summary of theory, research, and development is presented.	S. Barnes M. Becher et al
Component Evaluation and Specification Engineering. Task XX; Electrical - Indicating - Instrument Rectifiers	U S Govt Res Reports May 15 1959 LC $12.30 PB 136293	Large variety of assemblies were investigated. Semiconducting elements represented were silicon, germanium, selenium and copper oxide. Investigations on effects of temperature, frequency, thermal cycling, moisture-resistance cycling, and shelf-life storage.	L. H. Stember Jr.
Feedback Amplifier Design by Forward Equivalent Circuits	U S Govt Res Reports May 15 1959 LC $7.80 PB 136276	It is shown that by the introduction of unilateral forward equivalent circuit representations the analysis of feedback amplifiers is greatly simplified.	L. M. Vallese
Use of Parallel Thermocouples in Turbojet Engines	U S Govt Res Reports May 15 1959 LC $4.80 PB 137258	The use of parallel thermocouples in turbojet engines is desirable because such networks continue to indicate temperature until the last junction fails.	A. I. Dahl E. F. Fiock
Weighing Errors in Thermocouple Harnesses	U S Govt Res Reports May 15 1959 LC $9.30 PB 137770	The electrical characteristics of ladder-type thermocouple harnesses are described in general terms, followed by detailed analysis of several circuits.	G. F. Blackburn
Investigations of Surface Properties of Silicon and other Semiconductors	U S Govt Res Reports May 15 1959 LC $3.30 PB 135506	The low-energy electron diffraction work on silicon has been extended. The effects of quenching annealing, and ion-bombardment were observed.	H. E. Farnsworth J. A. Dillon R. E. Schlier
Pressure-Birefrinzence Relationships in Silicon Single Crystals	U S Govt Res Reports May 15 1959 LC $3.30 PB 136086	A brief report is given of the progress made in research to obtain information of the piezobirefringence of silicon monocrystals. Report covers 11/1/56-1/31/57. Quarterly Progress Report No. 2 2/1-4/30 LC $4.80 PB 136085 Quarterly Progress Report No. 3 5/1-7/31 LC $2.70 PB 136084 Final Report LC $6.30 PB 136083	A. A. Giardini
Preparation and Purification of Indium Arsenide	U S Govt Res Reports May 15 1959 LC $7.80 PB 137457	Indium arsenide was prepared in the furnace by either direct contact between the elements or by reacting arsenic vapor with molten indium. Properties of indium arsenide are presented.	D. P. Enright

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from Jan. 1, 1957 to Mar. 26, 1957. In subsequent issues, patents issued from Dec. 25, 1956 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT Review will appear periodically, the treatment given to each item being more detailed.

January 1, 1957
2,776,367 Photon Modulation in Semiconductors—K. Lehovec. Assignee: United States of America (Dept of the Army). A photomodulator comprising a unitary crystalline matrix including substantial amounts of germanium and silicon separated by a continuous n-p barrier.

2,776,372 Stabilized Transistor Oscillator—T. Ensink, J. Verhagen. Assignee: Hartford National Bank and Trust Company. A frequency stabilized oscillator system having a transistor amplifier comprising input and output circuits, and a bridge circuit comprising a series resonant circuit and a voltage responsive variable resistance element, said bridge circuit having an impedance approximating the input impedance of said transistor amplifier.

2,776,375 Pulse System—F. P. Keiper. Assignee: Philco Corporation. A transistor circuit including means responsive to the occurrence of a voltage pulse developed across an inductive element for increasing the emitter current to the saturation level during a portion of said pulse, and a resistive element in the path of emitter current flow for determining the magnitude of said flow.

2,776,379 Constant Frequency Power Supply—W. E. Sargeant. Assignee: General Motors Corporation. The combination with a source of power of varying frequency of control apparatus for converting input power of varying frequency to output power of constant frequency.

2,776,381 Multielectrode Semiconductor Circuit Element—E. G. Baldwin. A device comprising a cylindrical housing, a semiconductive wafer laterally supported therein, a pair of closely spaced electrodes making point contact with one side of said wafer, and a plurality of electrodes making point contact with the other side of said wafer.

2,776,382 Voltage and Current Regulation—J. L. Jensen. Assignee: Minneapolis-Honeywell Regulator Company. A transistor voltage regulator circuit utilizing switching principles to increase limits and efficiency of transistor operation as a current control device.

2,776,420 Transistor Indicator Circuits—H. J. Woll. Assignee: Radio Corporation of America. A device that provides a circuit for coupling an incandescent lamp to a transistor trigger circuit wherein the operation of said trigger circuit is not adversely affected by said lamp.

January 8, 1957
2,777,057 Radiation Powered Transistor Circuits—J. I. Pankove. Assignee: Radio Corporation of America. A compact radiation powered radio receiving system with circuit means including a semiconductor device or transistor, a crystal rectifier and a tunable circuit.

2,777,065 Negative Resistance Oscillator—R. L. Pritchard. Assignee: General Electric Company. An oscillator comprising a semiconductor device on n-p-n type construction, said device including therein two broad area p-n junctions, and appropriate external circuit connections.

2,777,092 Transistor Triggering Circuit—J. Mandelkorn. Assignee: United States of America (Dept of the Army). In combination: a thyratron, a pulse source means for triggering said thyratron, a point-contact transistor, and means in a circuit with the transistor's collector electrode and the grid of the thyratron for producing a triggering pulse at said grid whereby said thyratron is fired only by an applied bias to the cathode of the tube.

2,777,100 Rectifier Device—H. R. Ortega. Assignee: (Private Assignment). A plate type rectifier assembly utilizing a resilient spring coil in contact with the plates of said rectifier.

2,777,101 Junction Transistor—J. Cohen. Assignee: United States of America (Dept of the Army). A transistor with an n-type base, a p-type emitter and an n-type collector, an intrinsic layer connecting said base to said collector to form a transistor having a base whose thickness is predetermined.

January 15, 1957
2,777,949 Crystal Diode for Microwaves—H. B. Haard. Assignee: Telefonaktiebolaget, L. M. Ericsson. A crystal diode for use in connection with the mixing and detecting of microwaves of different lengths.

2,777,950 Oscillator—J. A. Doremus. Assignee: Motorola Incorporated. An oscillator which operates at a predetermined frequency including a point-contact p-n-p transistor, an electromechanical device with a magnetic vibrating reed structure, a winding positioned about said structure, said winding providing feedback for sustaining oscillations in the circuit, and said electromechanical device being the sole frequency selective means in the circuit.

2,777,956 Square Wave Generator—E. R. Kretzmer. Assignee: Bell Telephone Laboratories. A wave generator including a plurality of semiconductor asymmetrically conducting devices, said devices having a reverse conduction characteristic including a region of high resistance for applied voltages below a critical value, and a region of constant voltage with superimposed noise voltages above said critical voltage.

2,777,974 Protection of Semiconductive Devices by Gaseous Ambients. W. H. Brattain, C. G. Garrett. Assignee: Bell Telephone Laboratories. A device comprising a germanium body having contiguous zones of n-type and p-type material, an envelope and means for mounting the body in said envelope, and means for maintaining the p-type conductivity of the p-type zone consisting of an ambient atmosphere of oxygen sealed within said envelope.

2,777,975 Cooling Device for Semiconductive Elements—P. Aigrain. Assignee: Compagnie Generale de Telegraphie Sans Fil. In combination: a semiconductor body having a terminal, at least one heat absorbing electrothermic couple in thermal and electrical contact with said body, said electrothermic couple having a terminal, said semiconductor being cooled by a current flowing between said terminals.

2,777,979 Motor Controller—T. A. Hansen. Assignee: Teletype Corporation. In a control system for a motor having an auxiliary field winding, a source of energy, a pair of transistors, a source of alternating potential connected to the base electrodes of said transistors, and means for alternately energizing the transistors to supply energy from the source to the field windings.

January 22, 1957
2,778,885 Semiconductor Signal Translating Devices—W. Shockley. Assignee: Bell Telephone Laboratories. A device comprising a semiconductive body having therein an extended region of one conductivity type and a pair of zones of the opposite conductivity type on opposite

*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

sides of a constricted portion of said extended region, said pair of zones defining juxtaposed rectifying connections.

2,778,942 Electrical Control Apparatus—R. J. Ehret, W. Moore Jr. Assignee: Minneapolis-Honeywell Regulator Company. A vane control transistor oscillator having a resonant circuit in the base collector electrode path of the transistor, an inductive feedback to the emitter, and an asymmetrically conductive impedance in the base circuit as a means for establishing a biasing potential for the transistor.

2,778,956 Semiconductor Signal Translating Devices—G. C. Dacey, I. M. Ross. Assignee: Bell Telephone Laboratories. A device comprising a semiconductive body having a region of one conductivity type, source and drain connections, means contiguous with said region defining a rectifying junction therewith, means for reverse-biasing said junction, and means for enhancing minority carrier flow from the drain towards said junction.

2,778,978 Multivibrator Load Circuit—G. G. Drew. Assignee: Bell Telephone Laboratories. In a multivibrator circuit, a pair of electronic devices comprising either electron tubes or transistors, and an electromagnetic relay individual to and operative as an active load for each device.

2,778,980 High Power Junction Semiconductor Device—R. N. Hall. Assignee: General Electric Company. A junction transistor comprising a wafer of semiconductive material of one conductivity type, a first opposite conductivity type inducing electrode contacting one major surface of said wafer, a second electrode having a plurality of spaced apertures contacting the opposite major surface of said wafer, and a third electrode comprising a plurality of discrete junction type contacts.

January 29, 1957

2,779,134 Semiconductor Assembling Apparatus—P. E. Gates. Assignee: Sylvania Electric Products Inc. Apparatus for assembling a semiconductor element and a contact element in proper engagement, for sealing envelope portions together, thus completing an enclosing envelope, and for maintaining the elements in proper engagement.

2,779,877 Multiple Junction Transistor Unit—K. Lehovic. Assignee: Sprague Electric Company. A semiconductor crystal of a grown symmetrical multiple junction structure having two fused junctions disposed inwardly from opposed surfaces of said crystal, said fused junctions present in an end region of conductivity of said multiple junction structure.

2,779,901 Transistor Unit—G. R. Huard Jr. Assignee: Motorola Inc. A circuit element having a convex surfaced supporting member and a pair of electrically conductive sheets disposed on the convex surface in such a manner that they fit one another when the surface is flat and are spaced apart when the surface is in the convex form.

2,779,902 Semiconductor Unit—D. V. Geppert. Assignee: Motorola Inc. A circuit element including a semiconductive block having a pair of mutually inclined faces, an insulating panel disposed ni a plane traversing the line of juncture of said faces, and at least one metallic surface having a corner in contact with said block, said surface serving as an electrode for said block.

2,779,903 Semiconductor Unit—G. V. Geppert. Assignee: Motorola Inc. A device including a semiconductive block having a pair of faces forming a line of juncture, and a pair of metallic plates inclined to one another, the edges of said plates being in point contact with said line of juncture of the faces of the semiconductive block.

2,779,922 Transistor Test Set—G. M. Davidson. Assignee: American Bosch Arma Corp. A device designed to determine in a rapid manner with high accuracy and with a minimum of apparatus the following junction transistor parameters: emitter, base and collector resistances, and the amplification factor.

February 5, 1957

2,780,539 Process of Smelting Germanium—K. O. Seiler. Assignee: International Standard Electric Corporation. A process involving the treatment of a quartz crucible in order to form a thin film of amorphous carbon thereon, and the melting of germanium within the crucible.

2,780,569 Method of Making **p-n** Junction Semiconductor Units—C. W. Hewlett. Assignee: General Electric Company. A method involving the preparation of a monocrystalline germanium body having a trace of a donor impurity, and creating a coating of germanium and an acceptor impurity on said body by a process of evaporation and condensation.

2,780,725 Modulator Demodulator Limiter Transistor Circuits—M. L. Johanson. Assignee: Boeing Airplane Company. A circuit which may be operated directly from a single-ended source of modulation signals to be imposed on a carrier wave, or from a single ended source of a modulated carrier wave to be demodulated.

2,780,752 Semiconductor Network—R. W. Aldrich, J. S. Schaffner, J. J. Suran. Assignee: General Electric Company. Provided is a control network having stability in the presence of wide changes in ambient temperature.

2,780,757 Rectifier Structure—J. W. Thornhill, E. D. Jackson. Assignee: Texas Instruments Inc. A device comprising a rectifier unit, an annular resilient member attached to the top of said unit, cooling means at the bottom of said unit, means surrounding said unit so as to define an annular hermetically sealed space, means for mounting said assembly within a container.

2,780,758 Dry Disc Rectifier Assemblies—R. H. Zetwo. Assignee: Westinghouse Air Brake Co. A rectifier assembly wherein the length of short lead-in wires and the effective lengths of the contact members for the cells are of sufficient total length to dissipate the heat of soldering operations before the heat reaches the cell and adversely affects its characteristics.

2,780,759 Semiconductor Rectifier Device—J. L. Boyer, A. P. Colaiaco. Assignee: Westinghouse Electric Corporation. A device comprising a semiconductor rectifier cell, a metal support member in conductive contact with the cell, a flexible conductor connected to the other side of the cell, and gas-tight enclosing means for the cell.

2,780,765 Solar Energy Converting Apparatus—D. M. Chapin, C. S. Fuller, G. Pearson. Assignee: Bell Telephone Laboratories. Apparatus for maintaining the charged condition of a storage battery through the utilization of solar radiation, said apparatus comprising a storage battery, a photosensitive silicon junction device, and a rectifier.

2,780,767 Circuit Arrangement for Converting a Low Voltage Into a High Direct Voltage—P. J. Janssen. Assignee: Hartford National Bank and Trust Company; An oscillator system energized by a low voltage source comprising a transistor, means for deriving high voltage pulses from said oscillator system, a rectifier and a capacitor connected in series and means coupled to the capacitor for deriving a high voltage therefrom.

2,780,778 Phase Sensitive Strain Gage Amplifier Rectifier Circuit—A. A. Root, H. Clark. Assignee: General Electric Company. A rectifier circuit that is capable of deriving a variable amplitude reversible polarity alternating electric signal for feedback purposes.

2,780,782 Pulse Width Modulator—R. Bright. Assignee: Westinghouse Electric Corporation. A transistorized pulse width modulator capable of producing successive output voltage pulses of alternate polarity.

February 12, 1957

2,781,448 Gating Circuit—W. C. Struven. Assignee: U.S.A. (A.E.C.) A gating circuit having opposed crystal diodes in combination with a pair of vacuum tube control members, said circuit having a low voltage level output.

2,781,480 Semiconductor Rectifiers—C. W. Mueller. Assignee: Radio Corporation of America. A rectifier device having a stacked array of rectifying units enclosed in an insulating housing, a uniform coating of resistive material between said unit and said housing, whereby the applied voltage is uniformly distributed across each of said units.

2,781,481 Eemiconductors and Method of Making Same—L. D. Armstrong. Assignee: Radio Corporation of America. A device comprised of a wafer of *n*-type germanium, a metallic electrode fuzed to the surface of said wafer and a *p-n* rectifying junction disposed in said wafer adjacent to said electrode.

2,782,259 Calling Subscriber Using Transistor Oscillator in Subsets—T. L. Dimond. Assignee: Bell Telephone Laboratories. In a party line system, a transistor oscillator tuned to a different frequency at each station, and means for individually connecting each of said oscillators and a subscribers line.

February 19, 1957

2,782,267 Push-Pull Transistor Amplifier—J. W. Beck. Assignee: North American Aviation Inc. A two transistor circuit in which each transistor has its own complete and separate *d-c* bias path but contributes *a-c* output to a common output terminal between which and a point of reference potential an output load may be connected.

2,782,268 Instantaneous Automatic Gain Control Amplifier—W. E. Ayer. Assignee: U.S.A. (Navy Department). An amplifier having an instantaneous automatic gain control wherein the gain of an amplifier stage is instantaneously varied

by the signal so that the output can remain constant while the input signal varies.

2,782,303 Switching System—E. A. Goldberg. Assignee: Radio Corporation of America. A diode switching system which eliminates the effects of the capacitance introduced by the wiring of the diodes.

2,782,344 Binary Reciproconductive Circuit—S. Sharin. Assignee: Radio Corporation of America. A reciproconductive circuit comprising two series subcircuits each having a dual-electrode glow discharge device, a resistive element, a rectifying device, and a capacitor intercoupling the two subcircuits.

2,782,346 Measuring Apparatus—H. E. Darling. Assignee: The Foxboro Company. A measuring system formed of passive elements and adapted for energization by commercial supply line power without the need for an oscillator to produce alternating current of a high frequency.

February 26, 1957
2,783,168 Method for Preparing Rod-Shaped Crystalline Semiconductor Bodies — H. Schweikert. Assignee: Siemens-Schuckertwerke Aktiengesellschaft. A crystal pulling method of preparing a rod-shaped plural-zoned monocrystalline semiconductor body having adjacent zones of different conductivity type.

2,783,197 Method of Making Broad Area Semiconductor Devices—R. J. Herbert. Assignee: General Electric Company. A method of removing the rectification barrier short circuit from the p-n junction of an impurity diffused semiconductor device including an impurity contact by immersing said device in a water solution of an alkali hydroxide in spaced relation to an immersed electrode and applying a d-c voltage across the impurity contact and the electrode.

2,783,380 Frequency Controlled Transistor Oscillator—T. H. Bonn. Assignee: Sperry Rand Corporation. An oscillator consisting of a transformer, a pair of transistors coupled to a first winding, a variable potential source coupled between the transformer center tap and each of said transistors, and means for changing the magnitude of said variable potential source.

2,783,384 Electrical Inverter Circuits—R. L. Bright, G. H. Royer. Assignee: Westinghouse Electric Corporation. An electrical inverter circuit including a pair of semiconductor devices associated with a source of unidirectional voltage with means for rendering the devices alternately conducting and non-conducting.

2,783,417 Plug-In Rectifier Assembly—G. Eannarino. Assignee: Sarkes Tarzian. A mounting arrangement for plug-in rectifiers wherein rectifiers of different sizes and terminal spacings may be selectively employed with the same standard mounting arrangement and with a minimum of adjustment to confirm to different terminal spacings.

2,783,418 Metal Rectifiers—L. Hurst, A. Langridge, B. J. Gumm. Assignee: Westinghouse Brake and Signal Company Ltd. An a-c rectifier consisting of a semiconductive body, a cooling plate attached thereto, a tube for conveying coolant, and means for securing said cooling plate to said tube.

2,783,419 Rectifier—S. S. Fry. Assignee: Fansteel Metallurgical Corp. A selenium rectifier comprising a carrier electrode, a counter electrode on opposite sides of a selenium layer, and a blocking layer composed of hydrixethyl cellulose.

2,783,423 Shaded Pole Motor Control Apparatus—J. W. Streater, W. J. Popowsky. Assignee: Minneapolis-Honeywell Regulator Company. An arrangement for employing transistors as variable impedance elements for controlling the operation of a shaded pole motor.

March 5, 1957
2,784,121 Method of Fabricating Semiconductor Bodies For Translating Devices—C. S. Fuller. Assignee: Bell Telephone Laboratories. A method consisting of diffusing zinc into a body of n-type germanium in order to form a p-n junction therein, gold-coating the surface of said body, and heating said body to a temperature of at least 500°C, but below that at which a change in the concentration gradient perpendicular to the junction occurs.

2,784,262 Transistor Amplifier—R. P. Crow. Assignee: Motorola, Inc. A transistor unit for high quality distortionless signal amplification, said amplifier having a push-pull amplifier circuit with single-ended output.

2,784,296 Pulsing Apparatus For Semiconductor Translating Devices—F. Wohlman. Assignee: Hughes Aircraft Co. A pulsing apparatus including means for receiving, transporting, and handling semiconductor devices in a manner commensurate with desired handling characteristics necessary in connection with the delicate nature of the devices.

2,784,300 Method of Fabricating An Electrical Connection—P. Zuk. Assignee: Bell Telephone Laboratories. A method of connecting a lead to a germanium body which consists of fusing a portion of said body and said lead to form an alloy button on said body and mounting a platinum wire in the central portion of said button.

2,784,315 Transistor Pulse Oscillator—P. F. Moleman, J. P. Beyersberger. Assignee: Hartford National Bank & Trust Co. A circuit arrangement for producing periodic asymmetrical pulses of a width shorter than one half period of their repetition frequency.

2,784,358 Rectifier and Method of Making It—J. H. Scoff, H. C. Theverev. Assignee: Bell Telephone Laboratories; An asymmetrical conducting device comprising a germanium body containing not more than .001 per-cent of arsenic or antimony donor impurity, and a point contact electrode.

March 12, 1957
2,784,478 Electroforming Semiconductor Devices—B. N. Slade. Assignee: Radio Corporation of America. A treatment for a transistor device comprising the steps of passing alternating current between the collector and the base for a predetermined period, and then passing current pulses between the collector and the base while simultaneously passing a predetermined current between the emitter and the base.

2,784,479 Method of Manufacturing Rectifier Plates in Multiple—J. A. Roberts. Assignee: General Electric Company. A method consisting of coating a base plate with a selenium layer, forming a blocking layer upon the selenium, applying a layer of insulating material in the form of bands, forming the counter-electrode, dividing the base plate along dividing lines within said bands in order to form a plurality of rectifying elements.

2,785,095 Semiconductor Devices and Methods of Making Same—J. I. Pankove. Assignee: Radio Corporation of America. A device comprising a body of n-type germanium, a body of indium mixed with silicon oxide fused to a surface of said germanium body, and a p-n junction within said germanium body.

2,785,096 Manufacture of Junction Containing Silicon Crystals—W. A. Adcock. Assignee: Texas Instruments Inc. A method of manufacturing silicon crystals by growing said crystals from a molten bath under conditions which will produce a first layer of silicon having n-type conductivity, and a second layer of silicon having a p-type conductivity.

2,785,229 Line Circuit Using Transistors—A. H. Faulkner. Assignee: Automatic Electric Laboratories Inc. A line circuit for a telephone system in which semiconductor devices are utilized for registering calls and for performing switching operations.

2,785,236 Telephone Set With Amplifier—A. J. Chase. Assignee: Bell Telephone Laboratories. In a telephone system means for applying direct-current received from a central office to a transistor amplifier in a telephone set.

2,785,236 Transistor Amplifier for Alternating Current—R. L. Bright, R. O. Decker. Assignee: Westinghouse Electric Corporation. An alternating current amplifying device having an output transformer utilizing a magnetic core material having a rectangular loop hysteresis characteristic wherein the current conduction control devices are protected against excessive current flow.

2,785,349 Electric Semiconductor Devices—H. Wolfson, S. C. Shepard. Assignee: International Standard Electric Corporation. A point contact semiconducting cartridge shaped rectifier.

March 19, 1957
2,786,166 Electric Unsymmetrical Conductive Systems Particularly Dry Plate Rectifiers—S. Poganski. Assignee: Licentia Patent-Verwaltungs-G.m.b.H. A device having a first semiconductor, a pair of non-intrinsic semiconductor layers, a second intrinsic semiconductor, and two electrodes, one at each end of the four semiconducting layers.

2,786,167 Blocking Layer Rectifier—L. A. Esseling. Assignee: North American Philips Co. Inc. A rectifier assembly comprising a hollow metallic envelope, an insulating holder mounted within said envelope and a plurality of rectifying elements mounted in the chamber of said holder.

March 26, 1957
2,786,750 Process of Recovering Germanium Containing Material From Coal—M. Inagaki. Assignee: Sogo Henkyujo Zaidan Hojin (Coal Research Institute) A Corporation of Japan. A method of recovering germanium containing material from gas liquor derived from carbonization of germanium containing coal.

MARKET NEWS...

Sales

Factory sales of transistors during the first seven months of this year more than doubled the number sold this time last year, the Electronic Industries Association reported recently. Though sales dropped in July from the June level, sales were recorded over July 1958.

The following EIA chart shows transistors sales during the January-July period this year compared with the like 1958 period:

	1959 Units	Dollars
Jan.	5,195,317	13,243,224
Feb.	5,393,377	14,550,056
March	6,310,286	18,117,560
April	5,906,736	16,864,049
May	6,358,097	19,007,293
June	6,934,213	18,031,593
July	6,030,265	15,618,315
TOTAL	42,128,291	$115,432,090

	1959 Units	Dollars
Jan.	2,955,247	6,704,383
Feb.	3,106,708	6,806,562
March	2,976,843	6,795,427
April	2,856,234	7,025,547
May	2,999,198	7,250,824
June	3,558,094	8,262,343
July	2,631,894	6,598,762
TOTAL	21,084,218	$52,443,848

The United States Department of Commerce in its Mid-year Review of the Electronic Industries expects the semiconductor output during 1959 to increase about 40% over 1958—from an estimated $210 million to over $300 million. Semiconductor output (in dollars, is already double the total electron tube output of only a decade ago. Though the present magnitude of the industry will result in slower future growth rates, the inherent advantages of semiconductor devices have still been only partially exploited.

The United States Department of Commerce reports that Japanese output of semiconductors has gone from $10.7 million in 1957 to $24.5 million in 1958; production during the first quarter 1959 amounted to $11.5 million. The principal item in this group is transistors, of which 5.7 million units valued at $8.9 million were produc in 1957; 26.7 million units at $21.4 million in 1958; an 15.0 million units at $9.9 million in the first quarter 19

International General Electric Co., has ordered fro Toshiba Co., Japan a total of $2.2 million worth of tran sistors, transistor radios and receiving tubes for marke outside of the U.S. and Canada.

Cornell-Dubilier is expecting more than 20 millio transistors from Toshiba Co., of Japan in 1960.

Japanese manufacturers claim that more than 90% the transistors shipped to the U.S. so far have been use in the entertainment field. Several Japanese produce plan shortly to ship transistors to the U.S. earmarked fo industrial use.

Distribution

Fairchild Semiconductor Corp., has signed an agree ment with Schweber Electronics of Mineola, N.Y. to dis tribute their products. Schweber is Fairchild Semicon ductor's first distributor. Agreements are expected to b arranged shortly with distributors in other sections the country.

Texas Instruments Co., has named four European dis tributors. They are located in Copenhagen, Stockholm Paris and Zurick.

U.S. Transistor has appointed Walter G. Reinhau European Sales Manager with headquarters in Cologn Germany to direct the sale of their germanium an silicon transistors through sales representatives in Ger many, Greece, France, Turkey, Belgium, England, Portu gal and Italy.

New Companies

Crystalonics, Inc., Cambridge, Mass., a semiconducto firm formed last February, is now marketing its secon line of *p-n-p* transistors. The firm plans to move shortl to a 4,000 sq. ft. factory in Cambridge.

Transistor Specialties, Inc. will start operations th Fall in a new modern brick 10,000 sq. ft. building wit offstreet parking area consisting of 15,000 sq. ft. in th Expressway Industrial Park at Plainview. The Compan intends to specialize in the fields of Photo Electrics, Infra red, Data Processing, Ferrite Controls, Digital Control Transistor Circuitry and to design and manufacture elec tronic measuring, counting and detecting devices.

Prices

General Electric Co., Syracuse, N.Y. has recently intro

[*Continued on page 54*]

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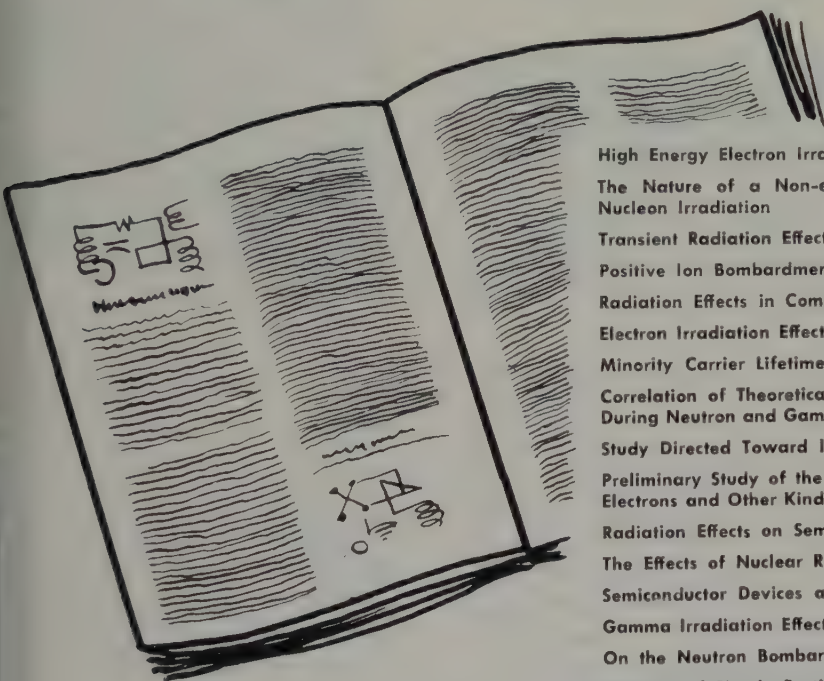

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New Products

Silicon Rectifier Line

Raytheon has announced a family of 18 silicon rectifiers which provide design engineers with full versatility. Maintaining a 40 amp average rectified current even at room temperature, low reverse current ratings, and peak operating voltages through 600 volts, the new rectifiers are available in three mechanical configurations to meet varied applications. Six types have fully insulated mounting studs, six have studs connected to anode, and six have studs connected to cathode.

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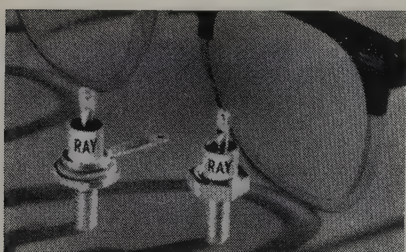

Transistor Frequency Response (f_T) Meter

Molecular Electronics Inc. announces a unique instrument for the measurement of transistor frequency response, f_T. Model F-20 covers the frequency range between 50 to 750 megacycles. Available in cabinet or for rack mounting. The equipment is self-contained, complete with batteries, and is adaptable for external power supply operation. Direct reading, can be operated by unskilled personnel; small, lightweight, portable, and provides an extremely accurate indication of the transistor's high frequency capabilities. Also available in lower frequency range models.

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Tiny Silicon Rectifier

New silicon rectifier by Audio Devices is designed for a variety of applications in radio, TV, tape recorders and other electronic instruments. Model E-5, a wafer-shaped 5/32" x 7/16" dia. electrically insulated rectifier, is available with solder or plug-in connectors. Five models, rated at 100 PIV, 200 PIV, 300 PIV, 400 PIV and 500 PIV each handle 750 ma with resistive load or 500 ma with capacitive load.

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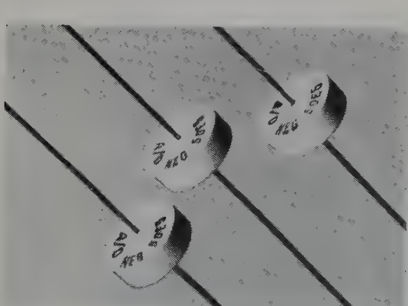

Silicon Controlled Rectifier

GE has announced a new line of silicon inverter-type controlled rectifiers specifically designed for dc to ac inversion, dc static switching, pulse width modulation, power equipment frequency conversion, and current limiting circuit breaker use. They have a maximum 12-microsecond turn-off time at their highest rated junction temperature, peak inverse voltage ratings of 100, 150, 200, 250 and 300 and are rated for operation in the junction temperature range from minus 65°C. to plus 125°C.

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Medium-Power Transistors

A new medium-power transistor series for applications in single-ended Class B drivers, output amplifiers for portable radios and TV, and other commercial units has been placed in production by Bendix. The transistor, called Yeoman and designated the 2N1176, A and B series, has a low saturation voltage of 0.3 Vdc, and can be supplied in 15, 40, and 60 voltage ratings with a 300 mAdc maximum collector current rating. Its linear current gain characteristics permit efficient switching and low distortion output.

Circle 82 on Reader Service Card

Transistor Radiator Series

Development of a new series of radiators 3AL-680, for cooling transistors has been announced by The Industrial Division of The Birtcher Corporation. These are similar to the company's 3AL-675 series of Transistor Radiators, except that they mount directly on the chassis or printed circuit board, thereby serving also as retainers. Sizes and modifications are available to cover the full range of TO-6, TO-7 and TO-9 packages. Material is aluminum with anodized finish.

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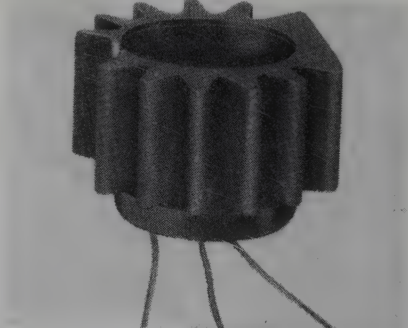

Silicon Detector Capsule

A subminiature "detector capsule" en-closing silicon light sensing element wa introduced by Hoffman Electronics re-cently. Type EA7 photo-voltaic detectio device is designed for use in application where higher light sensitivity and sma size are of prime importance. The tin unit will generate a minimum of 30 microamperes into a 1,000 ohm load an illumination level of 1,250 foot-candle of tungsten light at 2,800° K, color tem-perature. The detector cell has the ultr fast response time of less than 20 micro seconds, the exact speed depending the load impedance. The silicon lig sensing element has an active area about 0.13 by 0.05". It is hermeticall sealed in a rugged glass envelope capab of withstanding extreme environmen conditions.

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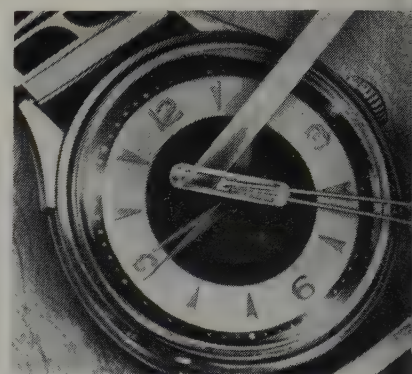

Tantalum Capacitor

The new Fansteel Gold-Cap Capacito is a polarized, tantalum electrolytic un capable of operating at full rated voltag in temperatures ranging from −55°C t +85°C with voltage derating at ambien temperatures from 85°C to 125°C. It offered with *proof in writing* of pre-tested reliability. This proof is base upon a series of rigid tests for checkin reliability. Each Gold-Cap is assigned registered serial number and all te results are recorded by this individu number. Meets Gold-Cap Specificatio No. 6CA-101, and is accompanied by it own certified record of test results.

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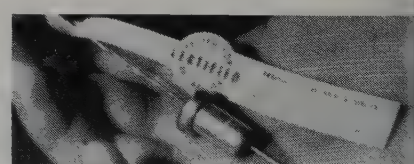


Silicon Rectifiers

RCA 1N536 thru 1N540, 1N547, an 1N1095 are hermetically sealed silico rectifiers of the diffused-junction type They are specifically designed for use i power supplies of industrial and militar equipment capable of operating at d forward currents up to 750 milliampere and temperatures ranging from −65° t +165° C. They have peak inverse-voltag ratings of 50, 100, 200, 300, 400, 600, an 500 volts, respectively, and a maximu reverse current of 5 microamperes a maximum rated peak inverse voltag and ambient temperature of 25° C. I addition, the maximum forward-voltag drop at a dc forward current of 500 milli-amperes (at an ambient temperature o 25° C) is 1.1 volts for the 1N536-40 an 1.2 volts for the 1N547 and 1N1095.

Circle 63 on Reader Service Card

iniature Selenium Diodes

New subminiature plastic-encapsulated elenium diodes have been developed by adio Receptor Company, Inc., subsidiary f General Instrument Corporation. apable of operating in ambient temper-tures from −50°C. to 100°C. without erating, the diodes come in eight types, ith peak inverse voltage ranges from) to 400 volts, at 12.5 ma. Maximum case ngth is only .380 inches for all eight ypes, with widths ranging from .340 nches for the 50 and 100 volt units up to 80 inches for the 400 volt type.

Circle 89 on Reader Service Card

ermanium Mesa Transistors

Two types of glass header germanium esa P-N-P transistors, designed specifi-ally for use at FM and TV frequencies, ere announced by Texas Instruments ncorporated, and are the forerunners of complete line of TI mesa entertainment evices. TI-361 features high gain at requencies of 200 megacycle for RF mplifiers and a typical noise figure of 5 db at the same frequency. A typical ircuit gain of 15 db in 100 megacycle F amplifier applications and a low 5.5 b typical noise figure are among the ighlights of the TI-360. Have an operat-g range of −55 to +85°C.

Circle 80 on Reader Service Card

ilicon Mesa Transistor

2N1252 is a low storage NPN diffused ilicon mesa transistor from Fairchild emiconductor Corporation. This device ombines low storage time with high cur-ent capability. It is ideally suited for use high current saturated switching cir-uits. The unit features guaranteed stor-ge plus fall times of 150 mμsec at I_C=150 ıA. Five megapulse operation is typical DCTL saturated circuitry. Has a DC urrent gain range from 15-45. Request ata sheet SL-11.

Circle 97 on Reader Service Card

iode Sealing Machine

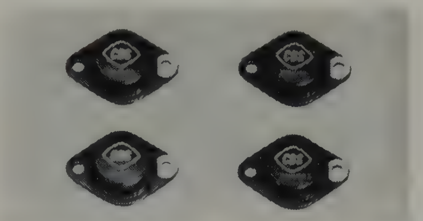
A new Six-Position Semi-Automatic ealing Machine, #3130, for making the nal seal on glass diodes has been intro-uced by Kahle Engineering Company. Production capacity is from 300 to 500 ealed diodes per hour. Consists of six omplete individual sealing machines nounted on a table, is 6′ long, 5′ high and ′ wide, weighs 600 lbs. and has pull-out ections for easy maintenance.

Circle 65 on Reader Service Card

Power Transistors

A series of complementary NPN-PNP power transistor lines has been announced by CBS Electronics. The NPN transistors have electrical characteristics identical to those of their PNP counterparts. The pairs feature high voltages, up to 100 volts, and proven reliability (exceeding MIL-T-19500A) for audio, control, voltage-regulation, servo and computer applications. All types in the line of 5 pairs have a maximum collector current of 3 amps, a minimum large-signal current gain of 30 (for a collector current of 0.5 amp), and a maximum thermal resistance of 3° C/W.

Circle 61 on Reader Service Card



High Current Recovery Diodes

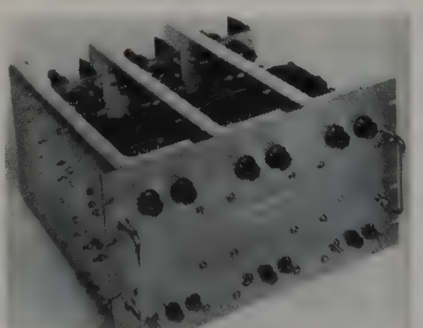
New silicon diode types combining high current capabilities with exceptionally fast recovery times for ideal application to computer switching operations were announced by Hughes Aircraft. The minimum forward-current specification (at 25°C and 1.0 volt) is 100 to 200 mA for these types 1N837-1N845. Typical capacity, at −2 volts, is less than 4 uuf. The diodes have a reverse resistance of 400 to 2000 meg ohms and an operating temperature range of −65°C to +150°C.

Circle 94 on Reader Service Card

Diode Ager & Tester

A modulated constant current source has been introduced by North Hills Electric Co. Designed especially for diode (zener and rectifier) ageing and life testing, the CS-125 has a range from 0.1 μa to 20 ma. @ up to 2250 v.d.c. Twenty-one completely independent supplies are contained in one rack, thus permitting about 10,000 5 volt zener diodes to be aged or life tested at one time.

Circle 74 on Reader Service Card



Computer Diode

A miniature, silicon junction computer diode designed by Microwave Associates, the MA-4223, is designed for use in computer circuits which require low capacity and exceptionally fast recovery time components. When switched from the forward bias with 10 milliamps current flowing to reverse bias of −5 volts, the complete recovery time is 4 millimicroseconds maximum. Typical performance is considerably below this figure. Operating temperature of these glass packaged diodes is from −65 to +100° C.

Circle 90 on Reader Service Card

Germanium Computer Transistors

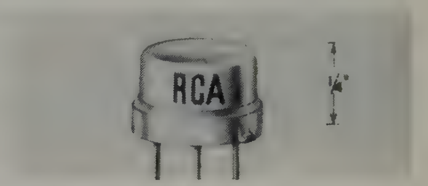
Texas Instruments announces 8 types of alloy germanium computer transistors, 4 P-N-P and N-P-N pairs. All feature emitter to base voltages of 25 volts and collector to emitter voltages ranging from 15 to 25 volts. The collector to base voltage for the P-N-P series (2N1303, 2N1305, 2N1307, 2N1309) is 30 volts and for the N-P-N, types (2N1302, 2N1304, 2N1306, 2N1308), 25 volts. All transistors also highlight a 300 ma collector current, 300 ma emitter current and a total device dissipation of 150 mw. Storage temperatures range from −65°C to 100°C.

Circle 81 on Reader Service Card

Mesa Transistors

RCA 2N1300 and 2N1301 germanium p-n-p diffused-junction mesa transistors; specifically designed for high-speed switching applications in commercial and military data-processing equipment in which high-frequency response and high power dissipation are important design considerations. Particularly useful in pulse-amplifier, inverter, flip-flop, and logic-gate circuits. Typical gain-bandwidth product of 40 Mc and 60 Mc respectively make these transistors especially useful in electronic computers operating at pulse-repetition rates up to 10 Mc.

Circle 62 on Reader Service Card



Power Transistor

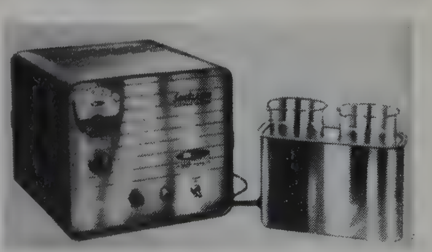
A new military-type germanium power transistor, designated 2N297A, has been announced by Bendix. It can be used in numerous military applications, such as in missiles and supersonic aircraft, and also in many commercial fields for high-current switching, audio amplification, regulators, power supply circuits, and oscillator circuits. Has a maximum collector voltage rating of 60 volts, and a maximum collector current rating of 5 amperes. It has a dissipation of 35 watts at 25° C. and 10 watts at 75° C.

Circle 83 on Reader Service Card

Ultrasonic Cleaner

A new, multi-purpose SonBlaster ultrasonic cleaning unit which can handle two different jobs at the same time in small parts cleaning, laboratory processing and investigation of various ultrasonic phenomena has been announced by The Narda Ultrasonics Corporation. Series 400 ultrasonically agitates the contents of two 400 ml Pyrex glass beakers. It is now possible to wash and rinse parts simultaneously, use two different solutions at the same time, use any chemical, acid, or alkali solvent in glass beakers, or use the stainless steel tank without beakers.

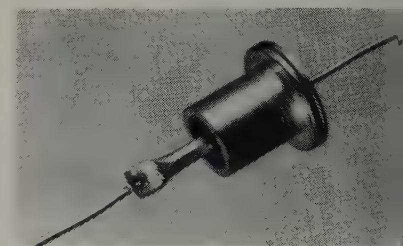
Circle 105 on Reader Service Card



Compensated Avalanche Diode

A new three-layer semiconductor device for more precise regulation of Zener voltages in electronic circuitry has been introduced by the Shockley Transistor Corporation. Principles of molecular engineering were employed to combine, in one tiny piece of silicon, functions which normally require several individual components. Dynamic resistance has been reduced to less than 1 ohm in the current range of 20 to 80 ma. Average voltage change is .043%/°C over a temperature range of −45°C to 150°C. This drops to less than .02%/°C over the 105°-1… range. Available in 12, 16, 20 and 24 v… units, in 1 watt and ¼ watt power ratings.

Circle 106 on Reader Service Card



Silicon Transistors

Westinghouse high power silicon transistors, when operated as a switch, are capable of controlling over 5 kw of power. Collector-to-emitter voltage ratings from 30 to 200 volts; maximum operating junction temperature of 150 degrees … and saturation resistance less than … ohm. Minimum current gain of 10 to … amperes collector current; maximum collector current rating of 30 amperes. The low thermal drop from junction to case coupled with higher temperature capability enables these power transistors to dissipate up to 250 watts internally.

Circle 66 on Reader Service Card

Silicon Triode Transistors

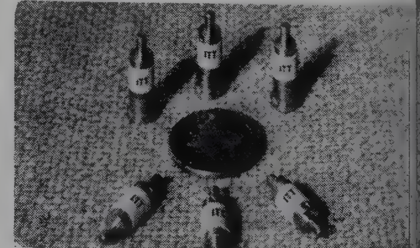
GE has announced a series of high frequency silicon triode transistors capable of dissipating 500-milliwatts at 25°C with no heat sink. These 5 transistors are "A" versions of 2N332 through 2N3… whose normal power dissipation is 1… milliwatts at 25°C. Fixed-bed construction provides the "A" transistors with higher mechanical reliability under severe conditions of shock, vibration, centrifugal force and temperature.

Circle 76 on Reader Service Card

Parametric Diode

A versatile parametric diode with many applications where high cut-off frequency is required was introduced recently by ITT Components Division. The semiconductor component achieves its low capacitance by its very small diffused "mesa" junction and attains a low series resistance through special control of the solid state diffusion processing. Development types include diodes with cut-off frequencies ranging up to 150 kilomegacycles, with zero bias capacitance as low as 0.4 micro-microfarad.

Circle 100 on Reader Service Card



Transistor Radiator

Model 3AL-672 Transistor Heat Radiator offers an inexpensive method of cooling diamond shape transistors as much as 30°C under typical operating conditions. Providing 12 square inches of radiating surface, the new Radiator is ideal for use with transistors when they are used above ground potential and heat cannot escape into the chassis. The device attaches with the transistor to the chassis and does not interfere with operation or servicing. The Radiator is made in one piece of aluminum instead of in several assembled beryllium fins. Finish is black anodize. Birtcher Corp.

Circle 71 on Reader Service Card

Transistor Etching Machine

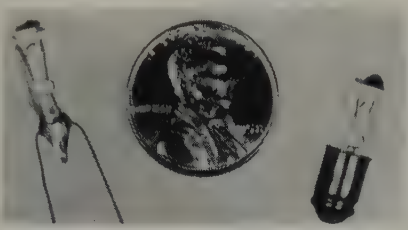
Carman Laboratories machine is intended to electrolytically etch and rinse transistors in an accurately controlled automatic cycle. Parts are hand-loaded on the indexing wheel which positions them accurately through five etch stations and four rinse stations. The jets and parts holder are made of materials that will withstand hot caustic solutions.

Circle 104 on Reader Service Card

Read-Through Lamp

Tung-Sol Electric has announced their development of the #4 lamp, a subminiature incandescent designed for computer use as a light source in a photoelectric readout application. Suitable also as a bright-light, direct end-on-viewed readout indicator, it is a 2.5 volt, 400 mA lamp less than ¼" in diameter and 13/16" in length (based). Its T-1 ¾ high-magnification lensatic bulb is designed to concentrate a ¼" spot pattern, ⅜" in front of the lamp for maximum read-through efficiency. It utilizes a single coil C-2R filament.

Circle 72 on Reader Service Card



I-F/Video Amplifier Transistor

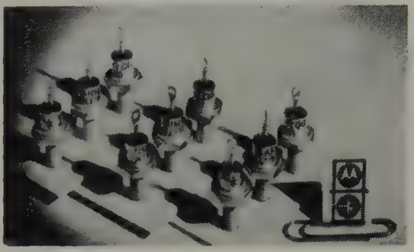
Transitron Electronic Corp. announces availability of the ST6006 and 2N1205 high frequency transistors for I-F and video amplifiers. Diffused Mesa techniques have been utilized in the manufacture of the ST6006 type which affords a typical power gain of 25 db @ 12.5mc. Similarly, the 2N1205 unit offers a typical power gain of 30 db @ 4.3mc. In addition to high gain characteristics these components present a low noise figure. Request Bulletin PB-64.

Circle 78 on Reader Service Card

Zener Diodes

Three new Motorola 10-watt zener diodes, the 1N1353 rated at 13.2 volts, the 1N1358 rated at 22 volts and the 1N1361 rated at 29.7 volts, are now available for military applications. These units meet or exceed the mechanical and environmental requirements of military specifications MIL-E-1/1236.

Circle 107 on Reader Service Card



Degreasing Machine

The King Company announces a new degreasing machine which combines the advantages of chemical vapor cleaning with portability and simplicity. An electrical thermal switch does away with cumbersome and confining water piping. If any electrical failure occurs, machine is turned off automatically. Placed on 4" wheels, it has a plug-in cord. Available in five models, ranging from 115 volts AC and 1500 watts to 220 volts AC and 5000 watts, in either single or three phase. 440 volt models are available upon request.

Circle 88 on Reader Service Card

(Continued on page 63)

duced a new series of five high frequency silicon triode transistors. These transistors, 2N332A to 2N336A are said to be capable of 500 mw dissipation at 25° C. They are priced in large quantities from $8.00 each for 2N332A to $17.50 each for the 2N336A.

Hoffman Electronics Corp., Semiconductor Division has announced a 30% decrease in prices on 1N429 Zener Reference diodes. Prices will be $7.50 each in single units in quantities up to 99; and at $5.00 each in quantities over 100. The division's new computor testing system has helped to reduce manufacturing costs on these items.

Minneapolis-Honeywell Regulator Co., is now in production on their 3N45 and 3N46 germanium power tetrode transistors. Prices range from $14.50 each in single units to $10.00 each in quantities of 5,000.

Texas Instruments Incorporated has introduced a series of high performance, all-purpose economy germanium transistors including types to sell as low as 50¢ in quantity lots. This low price range is made possible by the perfection of a new header manufacturing process and their new continuous Automatic Testing machines capable of testing 1,800 transistors an hour.

General Electric Company, Syracuse announces a new type of silicon controlled rectifier. Five types are available between 100 and 300 volt ratings. Prices range from $38 each for the 100 volt units to $116 each for the 300 volt device.

Radio Receptor Company, Inc., subsidiary of General Instrument Corporation has developed a new subminiature plastic-encapsulated selenium diode priced to sell from 15¢ to 35¢ in production quantities.

Expansions

Bendix Aviation Corporation has started construction on a new semiconductor products plant in Holmdell, N.J. This plant of 72,000 sq. ft. is scheduled to be completed early next year. It will handle the companies line of power transistors and silicon rectifiers.

Radio Corporation of America plans to build a new 120,000 sq. ft. semiconductor plant in Mountaintop, Pa. Their new plant will concentrate its production on Mesa transistors and silicon rectifiers. Production is expected to start by mid-1960.

Transistor Electronic Corp. has quadrupled its production area by adding a nearby 5,000 sq. ft. building to its headquarters in Minneapolis.

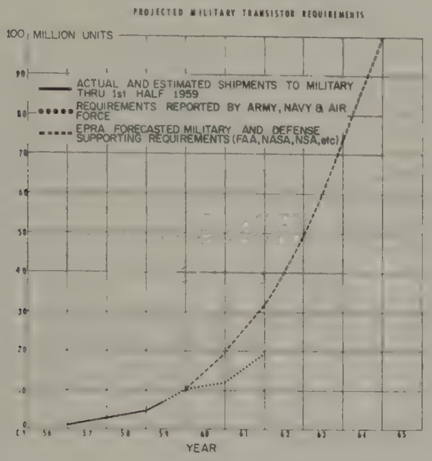
Universal Control, Inc., is erecting a new plant in Glen Cove, L. I. for turning out transistors. The new plant, which will be known as the C. P. Clare Transistor Corp., will replace the temporary building now being used in Glen Cove for this purpose. The Clare sales organization will market the new transistors.

Toshiba, Japan's largest manufacturer of transistors is rapidly nearing the completion of a new addition to its transistor plant and will become, accordingly, one of the largest manufacturers of transistorized radios in the world. The sales of their transistor radios in the American market has been increasing steadily. Last year it was

$5 million retail, this year they should exceed $10 million and in 1960 the company expects its sales in the U.S. to top $15 million.

Military

The Defense Department's newy reorganized Electronic Production Resources Agency (ERPA) has estimated that the military requirements for the next two and one-half



years will increase 100%, and for the next six years there will be a tenfold increase. It is estimated that military needs will reach a minimum total of nearly 20 million units by 1961, nearly doubling the 1959 military usage.

Contracts

Bendix Aviation Corp., and Ucinite division of United Car Fastener Corporation, are furnishing approximately 155,000 transistor oscillators for electroluminiscent instrument panels for Chrysler Corporation, 1960 line of cars. Sylvania who is supplying the electroluminiscent lamps hopes to add its own transistor oscillators for the 1961 Chrysler and Imperial lines.

Suppliers

The Esterbrook Company, a 101 year old writing instrument manufacturer, has begun to produce semiconductor parts such as washers, tabs, tools and jigs.

Grace Electronic Chemicals, Inc., suppliers of ultra high purity silicon, has available float zone refined silicon monocrystals, semiconductor grade, doped to customer specifications. Undoped monocrystals are characterized by resistivities of 800 ohm-cm or higher, and lifetimes in excess of 200 microseconds. Polycrystalline rods of the same purity, which have been given one floating zone pass, are available for those who wish to grow their own monocrystals in floating zone equipment.

Tang Industries, Inc., a new semiconductor material firm in Waltham, Mass., is planning to add a nearby 10,000 sq. ft. plant to their existing 3,000 sq. ft. facility. The firm is a supplier of custom silicon crystals.

Uni-Seal, Inc.'s new plant in Garwood, N.J. is now complete and running at full production capacity. The newly formed company is now able to make delivery on its wide line of transistor mounts, multi-headers, complete header and cover assemblies, individual terminals, crystal bases, diode housings, condenser and seals, and terminal strips.

CHARACTERISTICS CHART of NEW TRANSISTORS

Announced Between May 1, 1959 and June 30, 1959

MANUFACTURERS (In Order of Code Letters)

- ARA— Advanced Research Associates, Inc.
- AEG— Allgemeine Elecktricitats-gesellschaft
- AMP— Amperex Electronic Corp.
- AEI— Associated Electrical Industries Export Ltd.
- BEN— Bendix Aviation Corp.
- BOG— Bogue Electric Mfg. Co.
- CBS— CBS-Electronics
- CSF— Compagnie Generale
- CTP— Clevite Transistor Products, Inc.
- DEL— Delco Radio Div., General Motors Corp.
- EEVB— English Electric Valve Co., Ltd.
- ESEB— Edison Swan Electric Co., Ltd.
- FSC— Fairchild Semiconductors Corp.
- FTHF— French Thomson-Houston Semiconductor Dept.
- GECB— General Electric Co., Ltd.
- GE— General Electric Co.
- GEM— Great Eastern Mfg. Co.
- GTC— General Transistor Corp.
- HUG— Hughes Aircraft Co.
- HIVB— Hivac Ltd.
- IND— Industro Transistor Corp.
- LCTF— Labortoire Central de Telecommunications
- MIN— Minneapolis-Honeywell Regulator Co.
- MOT— Motorola, Inc.
- MUL— Mullard Ltd.
- NTLB— Newmarket Transistors Ltd.
- NPC— Nucleonics Products Co.
- PSI— Pacific Semiconductors, Inc.
- PHI— Philco Corp., Landsdale Tube Co.
- RAY— Raytheon Co.
- RCA— Radio Corp. of America, Semiconductor Div.
- SIE— Siemens & Halske Aktiengesellschaft
- SIL— Silicon Transistor Corp.
- SONY— Sony Corp.
- SPE— Sperry Gyroscope Co.
- SPR— Sprague Electric Co.
- SYL— Sylvania Electric Products Inc.
- STCB— Standard Telephone & Cables, Ltd.
- TKAD—Suddeutsche Telefon-Apparate-, Kabel und Draht-werke
- TRA— Transitron Electronic Corp.
- TFKG— Telefunken Ltd.
- TI— Texas Instruments
- TUN— Tung-Sol Electric, Inc.
- WEC— Western Electric Co., Inc.
- WEST— Westinghouse Electric Corp.

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. See code at start of charts
				P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	Gain: PARAMETER and (condition)	Gain: VALUE	
2N332A	2	NPN	Si	500		45		2.5	h_{FE}:I_C- 1ma	9	GE
2N333A	2	NPN	Si	500		45		2.5	h_{FE}:I_C- 1ma	18	GE
2N334A	2	NPN	Si	500		45		2.5	h_{FE}:I_C- 1ma	18	GE
2N335A	2	NPN	Si	500		45		2.5	h_{FE}:I_C- 1ma	37	GE
2N336A	2	NPN	Si	500		45		2.5	h_{FE}:I_C- 1ma	76	GE
2N350A	3Ø	PNPA	Ge	40W	1.2	50	40	5Kc	h_{FE}: .7A	30	MOT
2N351A	3Ø	PNPA	Ge	40W	1.2	50	40	5Kc	h_{FE}: .7A	45	MOT
2N376A	3Ø	PNPA	Ge	40W	1.2	50	40	5Kc	h_{FE}: .7A	60	MOT
2N394	5	PNP	Ge	150			10	4.0	h_{FE}:I_C- 10ma	20	GE
2N396A	2,5	PNPA	Ge	150	500		6.0	5.0	h_{fe}:I_c- 10ma	30-150	GE,GTC
2N448	2	NPN	Ge	65			15	5.0	h_{FE}:I_C- 1ma	8	GE
2N449	2	NPN	Ge	65			15	8.0	h_{FE}:I_C- 1ma	72	GE
2N469A	7	PNPA	Ge	50	1250	20	15	1.8	h_{fe}:I_e- 1ma	75	GTC
2N706	2,4,5	NPNME	Si	600	250	25	20	600	h_{FE}:I_C- 10ma	15 min	FSC
2N1078	3	PNPA	Ge	20W	3.0	60	45		h_{FE}:I_C-500ma	30	CBS
2N1086	2	NPN	Ge	65			9.0	8.0Ø	h_{FE}:I_C- 1ma	17	GE
2N1086A	2	NPN	Ge	65			9.0	8.0Ø	h_{FE}:I_C- 1ma	17	GE
2N1087	2	NPN	Ge	65			9.0	8.0Ø	h_{FE}:I_C- 1ma	17	GE
2N1097	2	PNP	Ge	140			16		h_{FE}:I_C- 20ma	34	GE
2N1098	2	PNP	Ge	140			16		h_{FE}:I_C- 20ma	34	GE

NOTATIONS

Under Use

1 - Low power a-f equal to or less than 50 mw
2 - Medium power a-f > 50 mw and equal to or less than 500 mw
3 - Power > 500 mw
4 - r-f/i-f
5 - Switching and Computer
6 - Low Noise
Ø - Revised Spec.
7 - Photo

Under Type

A - Alloyed
D - Diffused or Drift
F - Fused
G - Grown
H - Hook Collector
M - Microalloy
Me - Mesa
O - Other
S - Surface Barrier
UNI - Unijunction Transistor
Y - Symmetrical
§ - Tetrode

Under f_{ab}

* Maximum Frequency
\# Figure of Merit
Δ $f_{\alpha e}$
Ø Minimum
† Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under P_c

Ø - Infinite heat sink

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C: P_c (mw)	Max. Ratings @ 25° C: DERATING °C/W	Max. Ratings @ 25° C: V_{CB}	Max. Ratings @ 25° C: V_{CE}	Typical Characteristics: $f_{\alpha\beta}$ (mc)	Typical Characteristics: Gain: PARAMETER and (condition)	Typical Characteristics: Gain: VALUE	MFR. (See code at start of charts)
2N1115	2	PNP	Ge	150			15	5.0			GE
2N1118	2	PNP	Si	150		25		15*	h_{fe}	15	PHI
2N1119	2	PNP	Si		760	10			h_{FE}:I_E- 15ma	10	PHI
2N1120	3	PNPA	Ge	45W	1.2	80	40	5Kc	h_{FE}: 10A	30	BEN, CTP,MOT
2N1121	2	NPN	Ge	65			15	8.0	h_{FE}:I_C- 1ma	34	GE
2N1136	3⧄	PNPA	Ge	60W	1.2	60	40	.40	h_{FE}:I_C- 3A	75	BEN
2N1136A	3⧄	PNPA	Ge	60W	1.2	90	70	.40	h_{FE}:I_C- 3A	75	BEN
2N1136B	3⧄	PNPA	Ge	60W	1.2	100	80	.40	h_{FE}:I_C- 3A	75	BEN
2N1137	3⧄	PNPA	Ge	60W	1.2	60	40	.40	h_{FE}:I_C- 3A	110	BEN
2N1137A	3⧄	PNPA	Ge	60W	1.2	90	70	.40	h_{FE}:I_C- 3A	110	BEN
2N1137B	3⧄	PNPA	Ge	60W	1.2	100	80	.40	h_{FE}:I_C- 3A	110	BEN
2N1138	3⧄	PNPA	Ge	60W	1.2	60	40	.40	h_{FE}:I_C- 3A	150	BEN
2N1138A	3⧄	PNPA	Ge	60W	1.2	90	70	.40	h_{FE}:I_C- 3A	150	BEN
2N1138B	3⧄	PNPA	Ge	60W	1.2	100	80	.40	h_{FE}:I_C- 3A	150	BEN
2N1144	2	PNP	Ge	140			16		h_{FE}:I_C- 20ma	34	GE
2N1145	2	PNP	Ge	140			16		h_{FE}:I_C- 20ma	34	GE
2N1166	3	PNPA	Ge	50W	1.2	100	75	4Kc	h_{FE}: 25A	25	MOT
2N1195	2	PNPME	Ge	225		30		750	h_{fe}:I_e- 10ma	49	TI
2N1198	2	NPN	Ge	65			25	5.0	h_{FE}:I_C- 8ma	17	GE
2N1224	4	PNPD	Ge	120	500	40	40	30	h_{fe}:I_e-1.5ma	60	RCA
2N1225	4	PNPD	Ge	120	500	40	40	100	h_{fe}:I_e-1.5ma	60	RCA
2N1226	4	PNPD	Ge	120	500	60	60	30	h_{fe}:I_e-1.5ma	60	RCA
2N1273	2	PNPA	Ge	150	400	15	10	2.0	h_{fe}:I_c- 50ma	50	TI
2N1274	2	PNPA	Ge	150	400	25	10	2.0	h_{fe}:I_c- 50ma	50	TI
2N1276	2	NPN	Si	150		40		15†	h_{FE}:I_C- 1ma	9	GE
2N1277	2	NPN	Si	150		40		15†	h_{FE}:I_C- 1ma	18	GE
2N1278	2	NPN	Si	150		40		15†	h_{FE}:I_C- 1ma	37	GE
2N1279	2	NPN	Si	150		40		15†	h_{FE}:I_C- 1ma	76	GE
2N1310	2	NPNA	Ge	120	500	90		1.5	h_{fe}:I_e- 1ma	35	GTC
2N1311	2	NPNA	Ge	120	500	75		1.5	h_{fe}:I_e- 1ma	30	GTC
2N1312	2	NPNA	Ge	120	500	50		2.0	h_{fe}:I_e- 1ma	40	GTC
2N1358	3	PNPA	Ge		.80	80	40	10Kc	h_{FE}:I_C- 5A	25-50	DEL
2N1359	3	PNPA	Ge	45W	1.2	80	40	10	h_{FE}: 1.0A	55	MOT
2N1360	3	PNPA	Ge	45W	1.2	80	40	8.5	h_{FE}: 1.0A	90	MOT
2N1362	3	PNPA	Ge	45W	1.2	80	80	10	h_{FE}: 1.0A	55	MOT
2N1363	3	PNPA	Ge	45W	1.2	80	80	8.5	h_{FE}: 1.0A	90	MOT
2N1364	3	PNPA	Ge	45W	1.2	80	100	10	h_{FE}: 1.0A	55	MOT
2N1365	3	PNPA	Ge	45W	1.2	80	100	8.5	h_{FE}: 1.0A	90	MOT
2N1366	4	A	Ge	100	600		12	2.5	h_{fe}:I_e- 1ma	10	RAY
2N1367	4	A	Ge	100	600		12	2.5	h_{FE}:I_C- 10ma	20	RAY
2N1370	2	PNPA	Ge	150	400	25	10	2.0	h_{fe}:I_c- 50ma	80	TI
2N1371	2	PNPA	Ge	150	400	45	10	2.0	h_{fe}:I_c- 50ma	80	TI
2N1372	2	PNPA	Ge	210	380	25	15	2.0	h_{fe}:I_c- 50ma	45	TI
2N1373	2	PNPA	Ge	250	380	45	25	2.0	h_{fe}:I_c- 50ma	45	TI
2N1374	2	PNPA	Ge	250	380	25	15	2.0	h_{fe}:I_c- 50ma	70	TI
2N1375	2	PNPA	Ge	250	380	45	25	2.0	h_{fe}:I_c- 50ma	70	TI
2N1376	2	PNPA	Ge	250	380	25	15	2.0	h_{fe}:I_c- 50ma	95	TI
2N1377	2	PNPA	Ge	250	380	45	25	2.0	h_{fe}:I_c- 50ma	95	TI
2N1378	2	PNPA	Ge	250	380	12	7	2.0	h_{fe}:I_c- 50ma	200	TI
2N1379	2	PNPA	Ge	250	380	25	15	2.0	h_{fe}:I_c- 50ma	200	TI
2N1380	2	PNPA	Ge	250	380	12	7	2.0	h_{fe}:I_c- 50ma	100	TI
2N1381	2	PNPA	Ge	250	380	25	15	2.0	h_{fe}:I_c- 50ma	100	TI
2N1382	2	PNPA	Ge	200	380	25	15	2.0	h_{fe}:I_c- 50ma	80	TI
2N1383	2	PNPA	Ge	200	380	25	15	2.0	h_{fe}:I_c- 50ma	50	TI
2N1386	5	NPND	Si	300	500	25	25	60	h_{fe}:I_c- 10ma	45	RAY

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C: P_c (mw)	Max. Ratings @ 25° C: DERATING °C/W	Max. Ratings @ 25° C: V_{CB}	Max. Ratings @ 25° C: V_{CE}	Typical Characteristics: $f_{\alpha\beta}$ (mc)	Typical Characteristics: Gain PARAMETER and (condition)	Typical Characteristics: Gain VALUE	MFR. (See code at end of chart)
2N1387	5	NPND	Si	300	500	30	30	50	$h_{fe}:I_c$- 10ma	30	RAY
2N1388	6	NPND	Si	300	500	45	45	50			RAY
2N1389	6	NPND	Si	300	500	50	50	25			RAY
2N1390	6	NPND	Si	300	500	20	20	30			RAY
2N1392	7	PNPA	Ge	50	1250	20	20	1.0	$h_{fe}:I_e$- 1ma	40	GTC
2N1393	7	PNPA	Ge	50	1250	20	10	3.4	$h_{fe}:I_e$- 1ma	160	GTC
2N1394	7	PNPA	Ge	50	1000	10	10	1.0	$h_{fe}:I_e$- 1ma	50	GTC
2N1408	2	PNPA	Ge	150	500	50			$h_{fe}:I_e$- 1ma	25	GTC
2N1409	3,5	NPND	Si	2800	44	30	20	175	$h_{FE}:I_C$-100ma	30	PSI
2N1410	3,5	NPND	Si	2800	44	30	20	175	$h_{FE}:I_C$-100ma	60	PSI
2N1412	3	PNPA	Ge		.80	100	65	10Kc	$h_{FE}:I_C$- 5A	25-50	DEL
3N45	3,5	PNPA	Ge		1.0	60	30	.40	$h_{FE}:I_C$- 5A	40	MIN
3N46	3,5	PNPA	Ge		1.0	80		.40	$h_{FE}:I_C$- 5A	40	MIN
CTP1222	3	PNP	Ge		1.5	60	50		$h_{FE}:I_C$- 5A	20 min	CTP
CTP1530	3	PNP	Ge		.80	100	80	10Kc	$h_{FE}:I_C$- 5A	25-50	CTP
EW69	4	D	Ge	65	650	20	20	30	$h_{fe}:I_c$- 1ma	30	GECB
GET875	5	A	Ge	90	650	15	10	18	$h_{FE}:I_c$-150ma	50	GECB
SFT106	2	PNPA	Ge	80	620	18		5.0	$h_{fe}:I_c$- 1ma	35	CSF
SFT107	2	PNPA	Ge	80	620	18		7.0	$h_{fe}:I_c$- 1ma	55	CSF
SFT108	2	PNPA	Ge	80	620	18		10	$h_{fe}:I_c$- 1ma	100	CSF
SFT113	3	PNPA	Ge		4.0	30	15	.30	$h_{FE}:I_C$- 2A	40	CSF
SFT114	3	PNPA	Ge		4.0	60	30	.30	$h_{FE}:I_C$- 2A	40	CSF
SFT115	2	PNPD	Ge	150	330	40	50	30	$h_{fe}:I_C$- 1ma	60	CSF
SFT121	2	PNPA	Ge	175	290	24		1.1	$h_{FE}:I_C$-100ma	30	CSF
SFT122	2	PNPA	Ge	175	290	24		1.2	$h_{FE}:I_C$-100ma	50	CSF
SFT123	2	PNPA	Ge	175	290	24		1.3	$h_{FE}:I_C$-100ma	80	CSF
SFT126	2	PNPA	Ge	150	330	24		5.0	$h_{fe}:I_c$- 1ma	30	CSF
SFT127	2	PNPA	Ge	150	330	24		7.0	$h_{fe}:I_c$- 1ma	50	CSF
SFT128	2	PNPA	Ge	150	330	24		10	$h_{fe}:I_c$- 1ma	100	CSF
SFT135	5	PNPA	Ge	150	330	35		2.5	$h_{FE}:I_C$- 30ma	30	CSF
SFT136	5	PNPA	Ge	150	330	35		7.0	$h_{FE}:I_C$- 30ma	50	CSF
SFT141	2	PNPA	Ge	200	250	45		1.1	$h_{FE}:I_C$-100ma	30	CSF
SFT150	3	PNPA	Ge		4.0	80	40	.30	$h_{FE}:I_C$- 2A	40	CSF
SFT151	2	PNPA	Ge	150	330	24		.70	$h_{fe}:I_c$- 1ma	30	CSF
SFT152	2	PNPA	Ge	150	330	24		.90	$h_{fe}:I_c$- 1ma	50	CSF
SFT153	2	PNPA	Ge	150	330	24		1.1	$h_{fe}:I_c$- 1ma	80	CSF
XA124	2	PNPD	Ge	80		20		30	$h_{fe}:I_c$- 1ma	60	ESEB
XA131	2	PNPD	Ge	120		30		100	$h_{fe}:I_c$-1.5ma	60	ESEB
XA141	2	PNPD	Ge	120		30		30†	$h_{FE}:I_C$- 5ma	45	ESEB
XA142	2	PNPD	Ge	120		30		50†	$h_{FE}:I_C$- 5ma	45	ESEB
XA143	2	PNPD	Ge	120		30		75†	$h_{FE}:I_C$- 5ma	45	ESEB
XC141	3	PNPA	Ge		1.0	40	40		$h_{FE}:I_C$- 1A	70 max	ESEB
XC142	3	PNPA	Ge		1.0	60	40		$h_{FE}:I_C$- 1A	70 max	ESEB
XC155	3,5	PNPA	Ge		1.5	80	50	.65	$h_{FE}:I_C$- 1A	75	ESEB
XC156	3	PNPA	Ge		1.5	100	65	6.5Kc	$h_{FE}:I_C$- 1A	75	ESEB

NOTATIONS

Under Use

1 - Low power a-f equal to or less than 50 mw
2 - Medium power a-f > 50 mw and equal to or less than 500 mw
3 - Power > 500 mw
4 - r-f/i-f
5 - Switching and Computer
6 - Low Noise
∅ - Revised Spec.
7 - Photo

Under Type

A - Alloyed
D - Diffused or Drift
F - Fused
G - Grown
H - Hook Collector
M - Microalloy
Me - Mesa
O - Other
S - Surface Barrier
UNI - Unijunction Transistor
Y - Symmetrical
§ - Tetrode

Under f_{ab}

* Maximum Frequency
\# Figure of Merit
Δ $f_{\alpha e}$
Ø Minimum
† Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under P_c

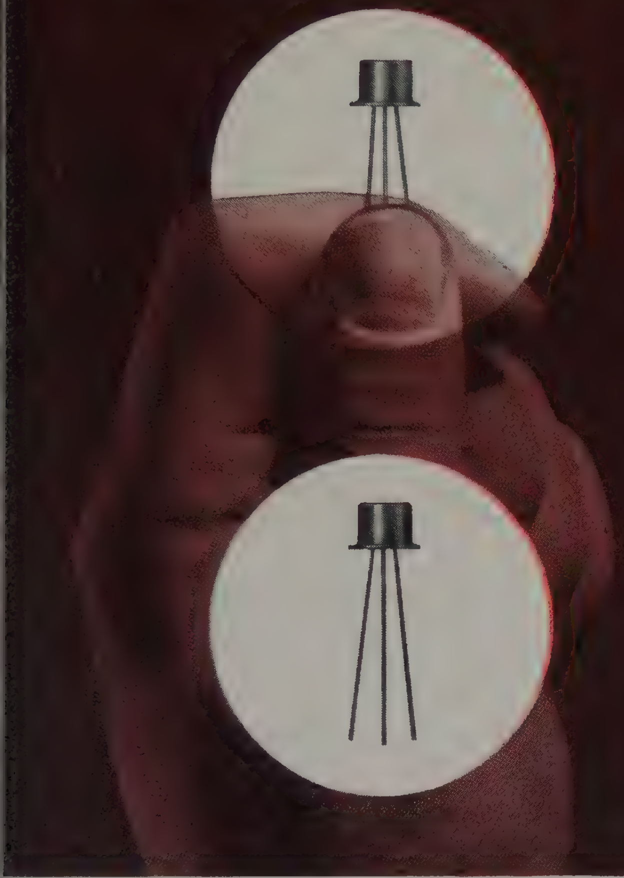
Ø - Infinite heat sink

The following manufacturers have announced that they have begun supplying the indicated previously registered transistors.

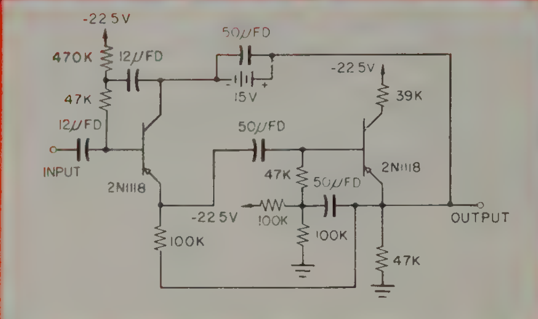
Bendix: 2N297A
CBS-Electronics: 2N297A, 2N1012
Clevite: 2N297A, 2N1011
Motorola: 2N331, 2N404, 2N1011
Raytheon: 2N438, 2N439, 2N440
Texas Instruments: 2N395, 2N396, 2N397

FROM PHILCO... **2 NEW** SURFACE ALLOY

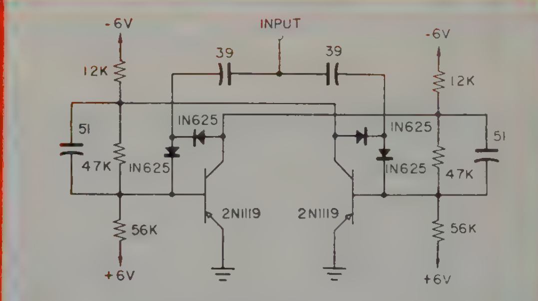
SILICON TRANSISTORS



For Proven Performance in High Speed Circuits at High Temperatures



High Input Impedance Amplifier—Z_{IN} > 2 megohms (25°C—125°C)



2 MCS Binary Counter—(—55°C to +125°C)

SAT* 2N1118 and 2N1119 offer 4 outstanding features:

1. Low Leakage Current
2. Very Low Saturation Resistance (Choppers, Switches)
3. High Base-emitter Breakdown Region
4. Controlled Input Characteristics

2N1428 and 2N1429 are Lower-priced Units with Comparable Characteristics for Low Voltage, High Beta Application.

*Trademark Philco Corp. for Surface Alloy Transistors

Philco continues its leadership in the Silicon high speed PNP field with these highly reliable field-proven SATs. In addition to their other superior characteristics, they have adequate frequency response to fill a large percentage of silicon transistor applications in both military and commercial circuits operating at high ambient temperatures. They are environmentally tested in accordance with MIL-T-19500 A. These two new types supplement and are the electrical equivalents of the widely used 2N495 and 2N496, offering the designer a choice of packages (TO-1 and TO-5). For very high speed switching applications, designers should consider Philco's NPN Diffused-base Transistor 2N1199. *Write for complete information, Dept. SC 1159.*

Immediately Available in Production Quantities . . . and 1-99 from your Philco Industrial Semiconductor Distributor.

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Industry News

CONFERENCE CALENDAR

The Following December 1959 IRE and Jointly Sponsore
Meetings Are Scheduled:

Dec 1-3 Eastern Joint Computer Conference, Statle Hotel, Boston, Mass. For Information: Jean H Felker, Bell Telephone Labs, Murray Hil N. J. Sponsored By: PGEC, AIEE, ACM.

Dec 1-2 4th Midwest Symposium on Circuit Theory Brooks Memorial Union, Marquette University, Milwaukee, Wisc. For Information: James D. Graham, College of Engnrg., Marquette University, 1515 W. Wisconsin Ave., Milwaukee 3, Wisc. Sponsored By: PGCT, Marquette University.

Dec 3-4 PGVC Annual Meeting, Colonial Inn & Desert Ranch, St. Petersburg, Fla. For Information: J. R. Neubauer, RCA, Bldg. 1-4, Camden 2, N. J. Sponsored By: PGVC.

Other Meetings Scheduled:

Dec 2-4 Electric Furnace Conference, Cleveland Hote Cleveland, Ohio. Sponsored By: America Institute of Mining, Metallurgical and Petroleum Engineers.

Dec 6-10 Annual Meeting, American Institute of Chemical Engineers, San Francisco, Calif.

Dec 26-31 Annual Meeting, American Association for the Advancement of Science; 126th Meeting. Morrison Hotel, Chicago, Ill.

Dec 28-30 American Physical Society Meeting, Pasadena Calif.

RESEARCH AND DEVELOPMENT

The National Bureau of Standards maintains an analog computer as a mathematical research tool to assist in the Bureau's scientific program. One of the examples representative of the Bureau's technical problems, in which the analog computer has aided research, is its analysis of transistor operation. Increasing application is being made of complex computing and control circuitry for airborne and field use. This equipment frequently requires electronic components of unusually high reliability to withstand possible extreme environmental conditions. The transistor is one component whose properties and applications are under intensive investigation for such use. Digital or pulse circuitry makes its own special demands on the transistor. Optimizing the design of the transistorized switching circuits that are employed in digital equipment makes it necessary to describe the physical transistor in a form consistent with the concepts of the circuit engineer. Therefore, the Bureau derived an equivalent circuit rep-

resentation of the transistor specifically for the non-linear operation encountered in large-signal switching circuits. It differs from previous circuits primarily by representing the input impedance as well as the transfer ratio even in the condition of saturation. The equivalent circuit was readily simulated on the analog computer for several modes of operation. Each simulation produced waveforms and amplitude responses that were in close agreement with limited experimental trials. The results provide a characterization of the transistor so that its performance in a switching circuit can be accurately predicted.

Hughes Aircraft Company metallurgists have perfected a method of casting optical-quality silicon for use in infrared sensors in military weapons systems. The new process permits volume production of silicon lenses, domes and flats. Until recently, it was necessary to "grow" individual crystals for each optical element which, in turn, had to be laboriously machined before use. Molds are designed to the approximate shape of the finished part and the castings given a final finishing on standard optical machinery. By holding castings to close tolerances, metal waste and finishing time is kept to a minimum. Hughes engineers disclosed that there is no severe size limitation on elements that can be made. Infrared domes with an outside diameter of more than eight inches have already been cast successfully.

A simple procedure for realizing standards of spectral radiant intensity has been devised by L. E. Barbrow, chief of the National Bureau of Standards photometry and colorimetry laboratory. By applying tabulated values to a tungsten-filament lamp standard that has been calibrated for luminous intensity at a specific color temperature, the lamp can easily be converted into a standard of spectral radiant intensity within the visible spectrum. As the uncertainty of spectral data derived is probably no greater than 3 percent over the visible spectrum, lamps calibrated for luminous intensity and for color temperature will provide a high degree of accuracy when used as spectral radiant intensity standards.

EUROPEAN R & D

Scientists from the Polish Academy of Sciences in Wroclaw report that they have undertaken an examination of the semiconducting properties of zinc and cadmium arsenides of the type A_3B_2. The measurements of electrical conductivity, Hall constant and thermo-electric power have shown that a *p*-type conductivity exists in both these compounds, unaffected by small deviations from the stoichiometry. At more elevated temperatures an intrinsic range seems to be attained, although the signs of the Hall constant and the thermoelectric power maintain their positive values. It is well known, that the II-V compounds show a marked tendency to be p-type semiconductors. This may be caused by a partial loss of the more volatile anionic component during the synthesis. In their case, the Poles say, such an explanation seems to be inadequate and the assumption of an anomalous mobility ratio u_n/u_p larger than 1 will be proposed. The comparison of the properties of zinc arsenide with those of the cadmium compound reveals the marked decrease of the energy gap and the increase of mobility with the increase in atomic number of the metallic component.

Yugoslav scientists believe they have found a better process for the preparation of high purity silicon. The alkali metal reduction of silicon halides is well known, for it has been used as the first preparation of elemental silicon. Nevertheless, the procedures hitherto described, on

the basis of such a reduction, are no longer satisfactory. A systematic investigation had been undertaken several years ago to find out the most convenient method for small scale preparation of pure silicon by reduction of silicon chloride and bromide vapour with sodium vapour at a temperature as low as possible. It has been established, in the present state of investigation, that the best results are obtained when the vapours of the reactants meet at a defined rate in a molybdenum or tantalum tube. Hydrogen or argon were applied as vapour carriers depending upon whether a molybdenum or tantalum tube, respectively, was used. In the hydrogen atmosphere the reaction proceeded less violently than in the case of argon, which may be explained by the participation of hydrogen in the reaction mechanism. Microcrystalline and amorphous silicon were obtained in a yield of about 90 per cent of the quantity required theoretically. The purity of the product was determined spectrographically and also by specific conductivity measurements. The results are satisfactory since the raw product obtained had the properties required for high purity silicon, which is used for semiconductor purposes. The work on a more exact determination of the reaction conditions as well as on improvement of the apparatus is now in progress.

ASSOCIATION ACTIVITIES

The Electronic Industries Association and the National Electrical Manufacturers Association (NEMA), the two major trade associations with interests in the semiconductor industry, have jointly announced some integrated programs designed to provide broader coverage in the areas of technical standards and marketing data for manufacturers and users of semiconductor devices. Along with the joint programs comes a definition of product scope for each trade group. NEMA's semiconductor activities essentially will encompass power and control rectifiers, excluding those intended for use in home entertainment devices. EIA's scope covers diodes and transistors generally used in signal and low-level applications as well as semiconductor devices used in home instruments. Power transistors are divided between the two associations' product scopes.

NEW PRODUCTS

(from page 53)

Parametric Amplifiers

Microwave Associates, Inc., announces availability of two new Parametric Amplifier mixer, down-converter units for very low noise signal reception. Model MA2-1000 is used for the 950-1250 Mc frequency range and MA2-1000L is designed for use in radar receivers in the 1250-1350 Mc range. Both models exhibit noise figures below 2 db with bandwidth of ¼ percent. Image rejection is better than 50 db down, and dynamic range is 30 db or better. They comprise a single stage of parametric preamplification using a suitable Varactor diode, a low noise mixer, down-converter stage with a 1N21E or MA-421B (1N21F) diode, and a third stage for coupling of the injected local Oscillator RF input.

Circle 91 on Reader Service Card

Battery Charger

Terado Company offers a 10 amp battery charger equipped to charge 6 or 12 volt batteries regardless of polarity. It will charge a 12 volt battery in five hours. This efficient, quick charge is made possible by two miniature silicon rectifiers which provide a full wave charge. The Terado Super Charger is equipped with an automatic overload circuit breaker and has a meter which indicates condition of the battery, as well as amperage charge rate.

Circle 101 on Reader Service Card

Epoxy Pellets

300% greater heat dissipation in germanium and silicon transistors is now made possible by aluminum filled epoxy E-FORM pellets. Manufactured by Epoxy Products, Inc., they enable transistors to withstand shock and vibration up to 100G's. They cure at temperatures as low as 85°C. Production-line dermatitis effects are eliminated. May be used in all-epoxy packages or in conjunction with a metal can and glass-to-metal seals. They are available in many shapes and sizes.

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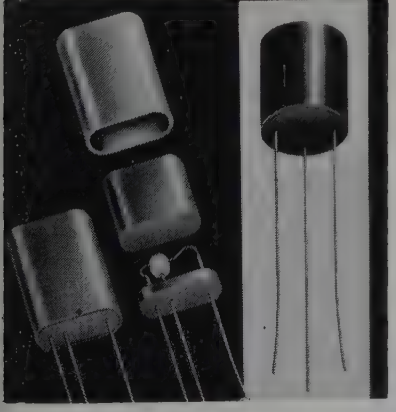

(from page 41)

below the "dropout" level.

The controlled switch (*CS*) is similar to the silicon controlled rectifier (*SCR*) in both physical construction and theory of operation. The controlled switch however, has a much greater firing sensitivity. It is therefore useful in many low level input applications that are not within the capability of the controlled rectifiers.

Much of the information presented in the following sections applies to both the controlled switch and the silicon controlled rectifier.

Logic Input Circuits

Three simple "*AND*" circuits are shown in *Figs. 23.1, 23.2, 23.3*. In each case, the circuits can be designed so that the *CS* will turn on only when there are inputs at both A and B. In *Fig. 23.1* one of the inputs is the anode source voltage while the other is the gate signal. In *Fig. 23.2* the gate is negative biased. The input signals are positive and must be limited in amplitude so that with either input present, the gate remains negatively biased but with both present, the gate to ground voltage exceeds the firing requirements and the *CS* turns on. In *Fig. 23.3*, the

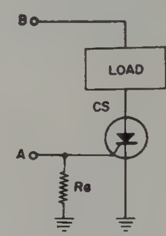

Fig. 23.1—"AND" circuit. Input signals are the anode source voltage and the gate signal.

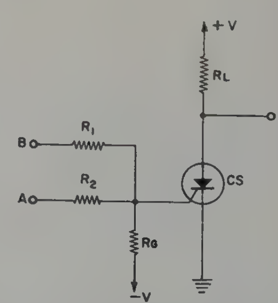

Fig. 23.2—"AND" circuit. Negatively biased gate.

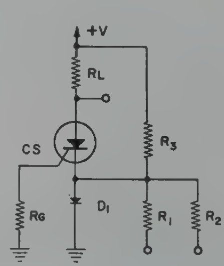

Fig. 23.3—"AND" circuit. Controlled switch normally biased "off."

CS is normally biased off by a positive cathode voltage. In this case the inputs must be negative. When both inputs are present, the positive bias is overcome and the cathode goes negative by an amount exceeding the firing requirements of the *CS*.

Figures 23.2 and *23.3* can be used as "*OR*" circuits by increasing the amplitude of the input signals so that either one will turn on the *CS*. *Fig. 23.4* shows another version of an "*OR*" circuit. In this case either a positive input at *A* or negative input at *B* will turn on the *CS*.

By combining the inputs shown in *Fig. 23.2* and *Fig. 23.3* a single circuit with four inputs is achieved. A variety of "*AND*" plus "*OR*" combinations can then be established. Additional inputs can be added to such a combination as long as biasing is properly set.

Figure 23.5 shows a sequential "*AND*" circuit which is useful for safety, protective, fusing, and related applications. Before power can be applied to R_L, three pulse inputs must be applied in the correct sequence.

With all three of the *CS's* off, the bias voltage at input *B* is 1/3 of the supply voltage, and at input *C* it is 2/3 of the supply voltage. *CS-2* will not turn on unless the voltage applied at point *B* exceeds 1/3 of the supply voltage. Similarly, *CS-3* will not turn on unless the voltage at *C* exceeds 2/3 of the supply voltage. *CS-1* on the other hand will turn on with an input at *A* equal to the normal *CS* firing requirements. Thus if the input pulse amplitudes are limited to less than 1/3 of the supply voltage, *CS-2* cannot turn on until *CS-1* has first been turned on. Also *CS-3* cannot turn on until both *CS-1* and *CS-2* have been turned on.

Circle 200 on Reader Service Card

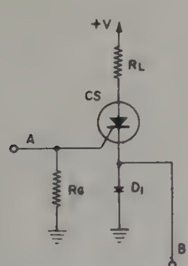

Fig. 23.4—"OR" circuit. A positive input at "A" or a negative input at "B" turns on the controlled switch.

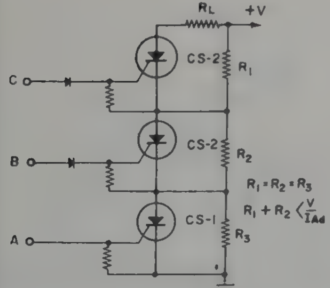

Fig. 23.5—Sequential "AND" circuit.

PERSONNEL NOTES

Appointment of Wallace A. Pond as Coordinator, Field Engineering, Radio Corporation of America Semiconductor and Materials Division, was announced recently. Mr. Pond received his B. S. degree in Electrical Engineering from the University of Illinois. He joined the RCA Electron Tube Division at Harrison, N. J., in 1946 as a Field Engineer and became a Sales Engineer in 1957. Since July, 1958, he has been a Field Engineer with the RCA Semiconductor and Materials Division.

Dr. J. Robert Spraul has been appointed acting manager of the research and development department of Rheem Manufacturing Company. Dr. Spraul will make his headquarters at the company's South Gate, California, plant. Dr. Spraul holds a Ph.D. degree in physical chemistry from the University of Indiana and has had a long career in research, including many years as supervisor of the physical chemistry group of Armour Research Foundation, Chicago, and as manager of the research and testing laboratory of General American Transportation Corporation, East Chicago, Indiana.

Four major appointments in top management were announced by Baird-Atomic, Inc. F. L. Foster, who has been vice president, marketing, becomes vice president, planning, a new post. Three major new divisions have been established within the company. The Spectrochemical Instrument Division is under direction of Dr. Jason L. Saunderson. Jack R. Carlin, formerly president of Atomic Associates, Inc., becomes manager of the company's Atomic Instrument Division. The company's Electronic and Special Products Division is directed by E. J. Cronin, manager. This group is concerned principally with the Baird-Atomic line of transistor test equipment and flame photometers.

The appointments of Mr. A. Olaf Wolff as Director of Research and Development, and of Mr. Harold T. Fargey as Manager of the Metal Sales Division, are announced by The Consolidated Mining and Smelting Company of Canada Limited. Mr. Wolff was formerly Manager of the Metal Sales Division and, in his new position, will co-ordinate the firm's technical research and development, market research and commercial development. Mr. Fargey, who succeeds Mr. Wolff, has been employed by the company since 1942.

Dr. Paul S. K. Chen has been appointed a senior engineer by the Semiconductor Division of Hoffman Electronics Corporation. Dr. Chen, assigned to the division's fabrication unit, will be responsible for the development of new diffusion techniques. He will be located at the division's new West Coast facility in El Monte, Calif. Dr. Chen holds a Master's degree in chemistry from the University of Oregon. He received his Ph.D. in physical chemistry from the University of Chicago.

Fairchild Semiconductor Corporation of Mountain View, California, announced the appointment of four engineers to supervisory positions in the Engineering Department. Robert Norman will head the Device Evaluation section. He is a graduate of Oklahoma State University with a BSEE. William Hafner, head of Electronic Instrumentation is a graduate of MIT with a BS. Brent Knudson, supervisor of the Product Specification Group, graduated from North Dakota State with a BSEE. Baden Parker, supervisor of the Design group in Electronic Instrumentation, graduated with a BSEE from the University of British Columbia.

Gerard J. Chesnes has been appointed manager of process control engineering at Silicon Transistor Corp. Mr. Chesnes, formerly a design engineer at RCA's semiconductor division, aided in the development of its high power silicon transistors. Prior to that he was in RCA's Princeton labs where he developed transistorized equipment.

The appointment of Leon C. Koenig as vice president of manufacturing was announced by Lindberg Engineering Company, 2450 W. Hubbard Street, Chicago 12, Illinois. Mr. Koenig, a company founder, has been assistant secretary and plant manager. Lindberg manufactures industrial heat treating and process line equipment and began operation in 1935.

Dr. Harper Q. North, president, Pacific Semiconductors, Inc. announced the appointment of Frank E. O'Brien to the newly created post of Director of Public Relations. Mr. O'Brien, who will also continue as PSI Advertising Manager, was formerly manager of the Portland, Ore. office of McCann-Erickson, Inc., and prior to joining Pacific Semiconductors, Inc. two years ago was vice president and manager of the Los Angeles office of Buchanan & Company, Inc., advertising.

Texas Instruments Incorporated has opened a regional personnel office in Elizabeth, New Jersey, to serve an eight-state area in an accelerated employment program. This office will assist all divisions of the company in selection of personnel from the states of New York, Massachusetts, Connecticut, Rhode Island, New Jersey, Delaware, Maryland, Pennsylvania and the District of Columbia. The new office is in the City Federal Savings and Loan Building, 1141 East Jersey Street.

Following a meeting of the Board of Directors, Mallinckrodt Chemical Works announced the appointment of an Executive Committee of the Board. Dr. John R. Ruhoff was appointed Chairman of this Committee. Other members named to the Executive Committee are Edward Mallinckrodt, Jr., Joseph Fistere, John E. Gaston, August H. Homeyer and Harold E. Thayer. Mr. Harold E. Thayer was appointed Executive Vice-President of the Company, also a newly created post.

Peter E. Price has joined the Electronic Chemicals Division of Merck & Co., Inc. at its Cherokee Plant, Danville, Pa. He will serve as Control Associate. The Cherokee Plant is engaged in the manufacture of ultrapure silicon for the electronics industry. Dr. Price will be concerned with applications research involving investigation of the crystalline structure of polycrystalline and monocrystalline silicon. Dr. Price is a graduate of Massachusetts Institute of Technology.

Clarence L. Norsworthy, Jr., of Dallas, Texas, and Morton P. MacLeod of Palo Alto, California, were elected to the Board of Directors of Knapic Electro-Physics, Inc., at a recent board meeting at Palo Alto. Norsworthy is a native of Dallas, Texas, where he is currently operating companies engaged in petroleum, mining, and electronics. MacLeod is a lawyer and partner in the law firm MacLeod & Gunn. Also included was the election of Robert D. Yeaman as Vice President of Manufacturing and Engineering and George M. MacLeod as Vice President of Sales.

Five key organizational appointments were announced by Raytheon Company's Semiconductor Division. Leo F. Leary is the new manager of manufacturing. Plant managers for the Newton-Brighton plant and the Lewiston plant will report to Mr. Leary. Henry F. Schunk, former manager of the Newton-Brighton plant, will move to Lewiston, Maine to set up the new 140,000 square foot plant there for 2,000 workers. Ray T. Mijanovich will take over as manager of the Massachusetts production facilities. Dr. Walter F. Leverton has been named engineering manager of the Semiconductor Division. Raymond J. Barber is the new controller.

Appointment of Melvin Barmat, thermoelectric physicist-engineer, as Manager of the newly-created Thermoelectric Division of General Instrument Corporation has been announced. He will head up a scientific group developing thermoelectric devices, using both nuclear and conventional fuels, which produce electricity by application of heat to semiconductors. A graduate of Hofstra College, Hempstead, N.Y., Mr. Barmat also attended Cooper Union School of Engineering and the Polytechnic Institute of Brooklyn.

The appointment of Donald E. Smith to the newly-created position of product sales manager—diodes and rectifiers, for the Semiconductor Division of Sylvania, has been announced. Mr. Smith, who has been a semiconductor sales engineer since 1957, will continue to have his offices at division headquarters in N.Y.C. He is responsible for developing and administering market research, product planning, sales, advertising and merchandising activities, for the division's full line of diodes and rectifiers. A native of Sioux Falls, S. D., Mr. Smith is a graduate of Purdue University with a Bachelor of Science degree in electrical engineering. He is a member of the Tau Beta Pi and Eta Kappa Nu fraternities.

Frederick R. Lack, noted electronics engineer and executive, has been elected a director of the Sprague Electric Company, it was announced by Robert C. Sprague, chairman of the board and treasurer, following a special meeting of the board of directors. The addition of Mr. Lack increases the membership of the Sprague board to eleven directors. Mr. Lack is a former director and vice-president of the Western Electric Company, retiring in August, 1958.

Frank P. DeLuca, Jr. has been appointed executive vice president of Acoustica Associates, Inc. of Plainview, Long Island, N. Y. and Los Angeles, California, manufacturers of ultrasonic equipment for missiles, aircraft and industry. Mr. DeLuca, who is a director of the corporation, was formerly vice president and general manager of Acoustica's Western Division.

New Literature

An inhibitor that displaces and seals out water and moisture, protects metal surfaces against corrosion, and lubricates is the subject of a new six-page illustrated folder just released by Corrosion Reaction Consultants. Called CRC 2-26, this liquid formula has been especially developed for manufacturing and maintenance use in the electrical and electronic equipment fields. The folder includes an explanation of how CRC 2-26 works, its benefits, advantages and applications, factual case histories and details on its physical specifications.

Circle 125 on Reader Service Card

A catalog on graphite usage in semiconductor production is being produced by the United Carbon Products Company. Prepared with stiff covers and new "Latch Lock" ring binder, this new catalog No. SC-659, permits the addition of technical data sheets whenever new developments occur. It is nicely illustrated and covers sections on semiconductor graphites, specialized graphite machining problems, methods of graphite quality control, means of planning, scheduling and expediting orders, typical physical properties of various grades of graphite, stock sizes and prices.

Circle 126 on Reader Service Card

Copper-cored #446 alloy glass sealing wires are described in the second and third of a series of bulletins on cored and clad wires published by Texas Instruments Incorporated, Metals & Controls division. The 2-page bulletins, IND-22 and IND-23, describe the two more important compositions, 2:1 and 3:1 ratios of overall wire diameter to the diameter of the copper core, respectively. (The first data sheet of this series dealt with copper-cored #52 alloy glass sealing wire in a 2.6:1 ratio.)

Circle 127 on Reader Service Card

Transitron Electronic Corp., offers a concise two-page reference piece, complete with package photos, listing descriptions, important data and useful applications of five new silicon transistor developments. Included for additional reference is an itemized inventory with operating characteristics of a broad and complete line of silicon transistors available from stock.

Circle 128 on Reader Service Card

RCA Semiconductor Products Handbook HB-10, devoted exclusively to data on RCA semiconductor devices including transistors and silicon rectifiers is now available. Available either in conjunction with HB-3 Tube Handbook, or separately, at RCA's subscription price. This Handbook has been compiled to meet the requirements of electronic equipment design engineers primarily, but will prove useful to all who have need for up-to-date technical information on RCA semiconductor devices.

Circle 129 on Reader Service Card

A new technical guide to automatic soldering with solder preforms is now available from Alpha Metals, Inc. Titled, "Guide to Automatic Soldering," it offers data on solder preforms, their selection and use, converting to automatic soldering, and new, flux-filled washers for automatic soldering. Included is an offer of technical information on solder alloy and flux selection. Information on allied problems is offered in two other Alpha bulletins: "Tips on Soldering," and "Flux-Finder Guide."

Circle 131 on Reader Service Card

The availability of the engineering bulletin covering its new power transistors has been announced by Silicon Transistor Corp. The new STC types, 2N1069 and 2N1070, are NPN high power silicon transistors featuring extreme low saturation resistance. Form #1953 includes ratings and electrical characteristics charts, curves and other pertinent data.

Circle 132 on Reader Service Card

A 30-page catalog on neon and incandescent indicators, both conventional and transistorized; push button switches; combination indicators-switches; decimal readout devices and other display panel components is offered by Transistor Electronics Corp. Also includes a Transistor-Diode Tester.

Circle 133 on Reader Service Card

A one-page brochure discusses additions to the Southwestern Industrial Electronics line. It includes photographs of and specifications for the model R-3 transistorized voltmeter, model N-1 transistorized signal generator, model T-1 vibration meter, model R-2 vacuum-tube voltmeter, ARP audio response plotter, model D-3C DC amplifier, and model K-1 microsource. Full data is included.

Circle 134 on Reader Service Card

A new two-color four page brochure has been produced by Schweber Electronics to aid buyers and engineers in the selection of the correct Amphenol AN/MS Connector (Mil-C-5015C and Mil-C-5015D). This handy reference shows available AN/MS insert contact arrangements and contains a quick reference for insert specifications.

Circle 135 on Reader Service Card

J. T. Baker Chemical Co., has just published a completely new and much more informative Technical Information Brochure on Baker PL-11, an acrylic-type polymer developed in their Research Laboratories.

Circle 136 on Reader Service Card

A comprehensive, 130 page manual covering basic theory, design characteristics and applications for zener (voltage limiting) diodes has just been announced by Motorola for a nominal charge. It is intended to serve as a guide in the use of this component. Chapter headings include: Characteristics of Silicon Zener Diodes, Design Considerations, Regulated Power Supplies, Surge Protection, A.C. and D.C. Amplifiers, Temperature Compensation and Impedance Cancellation, New Approaches in Zener Diode Applications, and Specifications and Testing Methods.

Circle 141 on Reader Service Card

A new technical publication, SPAN, has been introduced by the Semiconductor Division of Hoffman Electronics Corporation. SPAN (Semiconductor Product Application News) is a bi-monthly publication and contains technical data and application information on silicon semiconductor devices. Available to persons engaged in administrative, purchasing or engineering activity relating to semiconductor devices.

Circle 137 on Reader Service Card

A new booklet, "Entertainment Transistors for Every Design Approach," has been made available by Sylvania. The 32-page booklet contains maximum ratings and electrical characteristics for a wide variety of PNP, NPN and "drift" transistors designed for use in hi-fi, toys, organs, intercoms, portable, shortwave and auto radios. The booklet also includes diagrams illustrating the mechanical specifications and connections of all types in Sylvania's transistor line.

Circle 138 on Reader Service Card

Bendix Semiconductor Division makes available their newly revised (9-1-59) Replacement Chart For Transistors. Lists 300 Type numbers and Bendix replacements.

Circle 130 on Reader Service Card

"How to Use HumiSeal Protective Surface Coatings in Electronic Applications" is the subject of a 20-page booklet released by Columbia Technical Corporation. This booklet covers such highly informative phases of applying humidity-proof protective surface coatings as conventional dipping procedures and what to do for dipping, draining and air-drying and curing. It also covers such subjects as vacuum impregnation, spray coating and masking, silk screen coating, roller coating, etc.

Circle 139 on Reader Service Card

A new characteristics and replacement guide for semiconductor diodes has been made available by Sylvania. The 12-page booklet contains complete data on the ratings and electrical characters of all Sylvania types as well as a replacement guide to virtually all Electronic Industries Association registered diodes. The booklet features a section on Sylvania's latest diode manufacturing equipment including the company's recently announced digital automatic tester and classifier which verifies up to 16 separate parameters.

Circle 140 on Reader Service Card

Index to Advertisers

Aeroprojects, Inc. 52
Allied Chemical Corp.
General Chemical Div. 9
Allied Radio Corp. 54
Anchor Metal Co., Inc. 60
Art Wire & Stamping Co. 70
Avnet Corporation 71

Birtcher Corporation, The 64

Ceramic-Metal Assemblies Corp. 66
Cohn, Sigmund, Corp. 65
Custom Scientific Instruments, Inc. 54

Dice, J. W. Co. 70

Eagle-Picher Co., The 6
Electronic Laboratory Supply Co. 70
Electronic Measurements Co., Inc 72
Epoxy Products, Inc. 13

Fairchild Semiconductor Corp. . 4

General Electric Co.
Semiconductor Products Dept. 10
Glass Beads Corp. 68

Hoffman Electronics
Semiconductor Division 11
Hughes Aircraft Co.
Semiconductor Division 66

Indium Corp. of America, The .. 62

Kahle Engineering Co. 16
Kanthal Corp., The 55
Kessler, Frank Co., Inc. 64
Knapic Electro-Physics, Inc. Cover III

Lepel High Frequency Labs, Inc. 61

Manufacturers Engineering & Equipment Co. 60
Merck & Co., Inc. 15
Milgray .... Covers IIA & IIB

North Hills Electric Co., Inc. 64

Philco Corporation
Lansdale Tube Co., Div. 59

Radio Corporation of America .. 67
Radio Receptor Company, Inc. .. 7
Raytheon Company
Semiconductor Division 2, 3

Sarkes-Tarzian, Inc. 8
Snelling & Snelling 68
Sprague Electric Co., Cover IV, 14

Texas Instruments Incorporated Cover II, 1, 69
Textool Products, Inc. 55

U. S. Semiconductor Products, Inc. 12
United Carbon Products Co., Inc. 18

Westinghouse
Semiconductor Division 53